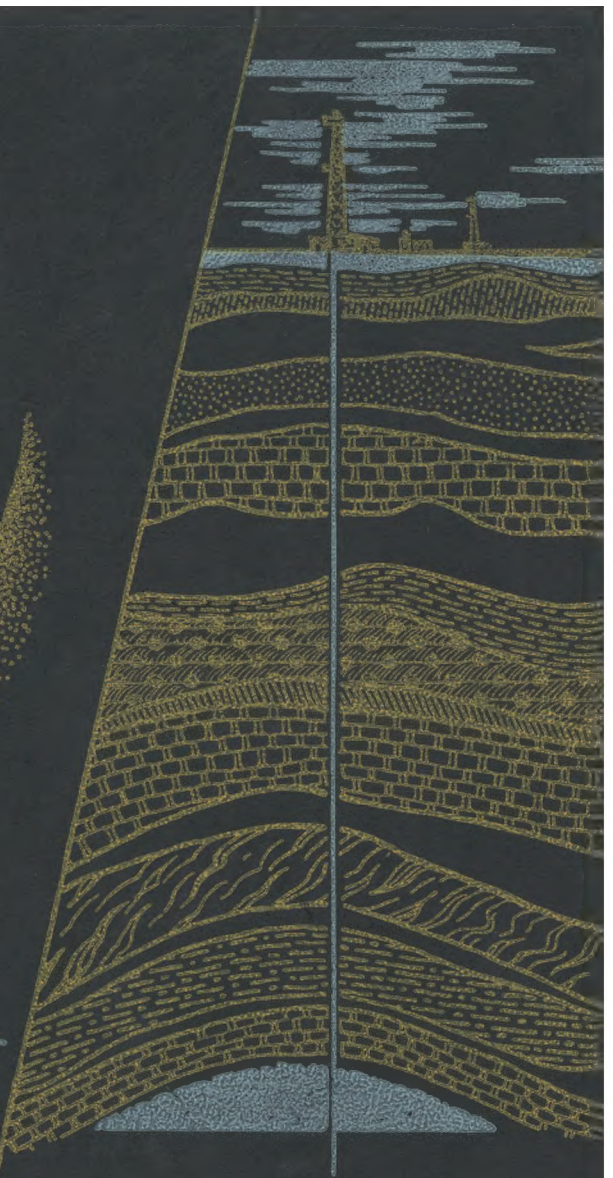


# The Story of

# OIL

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NEW WEALTH FOR CANADA

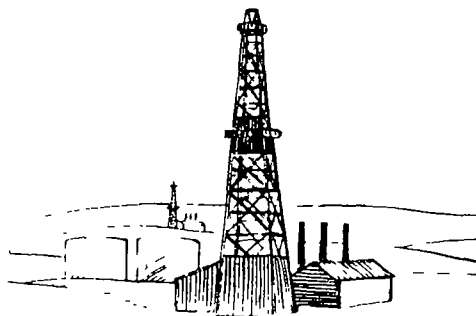


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# THE STORY OF OIL

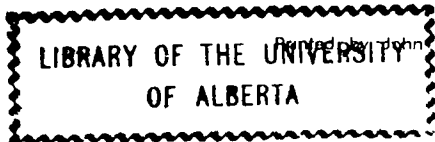
By G. W. AUXIER, K.C.



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## Foreword

Since the discovery of the Leduc field in February 1947, the development of the oil industry in Western Canada has been rapid. It may well be that it will usher in an era of great industrial expansion, at the least it will add a substantial source of new wealth to our thriving agricultural economy.

The Western Canada Petroleum Association includes amongst its members practically all of the individuals, firms and corporations, large and small, who are engaged, directly or indirectly, in the western oil industry. They are convinced that the long range welfare of the industry and the ultimate prosperity of Western Canada go hand in hand. In the belief that the people of the West are interested in learning something of the industry which may mean so much to their future, the Association presents this booklet.

To the many members of the industry who assisted Mr. Auxier in preparing the material contained herein, the Association extends its thanks. It also acknowledges the considerable assistance derived from "This Fascinating Oil Business" and extends special thanks to Mr. Max W. Ball, the author and Messrs. McClelland & Stewart, the Canadian publishers of that excellent work.

Western Canada Petroleum Association

Calgary, Alberta.

May 1, 1951

## The Origin of Oil

The word "petroleum" means, literally, "rock oil." It came from the rocks and was so named to distinguish it from animal and vegetable oils. Although still called a mineral, petroleum is now generally conceded to be also an organic substance.

The entire recorded history of the world goes back only a few thousand years. This being so it is difficult to think in terms of hundreds of millions of years, but it seems to be accepted that oil had its origin in those distant days.

The earth, the geologists tell us, is some three thousand million years old. During all this period the earth's surface has been undergoing gradual change. Particles of the land surface, moved by wind and water from one point to another, have been working slowly towards the seas and accumulating there in much the same way that sand bars and mud flats are built up at the mouths of great rivers. It is thought that the weight of these deposits caused gradual depression of the earth's crust in some places, and corresponding uplift in others, raising land areas out of the seas, and diverting the seas into other low-lying land areas. Undoubtedly such changes are still going on, but the process is too slow to be noticed in the space of a few hundred years.

In the Cambrian period, which ended some 430 million years ago, the first traces of vegetable or animal matter began to appear. As time advanced through succeeding millions of years, biological matter also advanced and developed. By the Devonian period, which ended about 255 million years ago, corals and other sea creatures were very prevalent. This period is important to us as during that time was laid down the oldest formation from which oil has been produced thus far in Western Canada.

At various times during these millions of years, the western prairies, in common with some other parts of the earth, were covered by ancient seas. After the appearance of life on

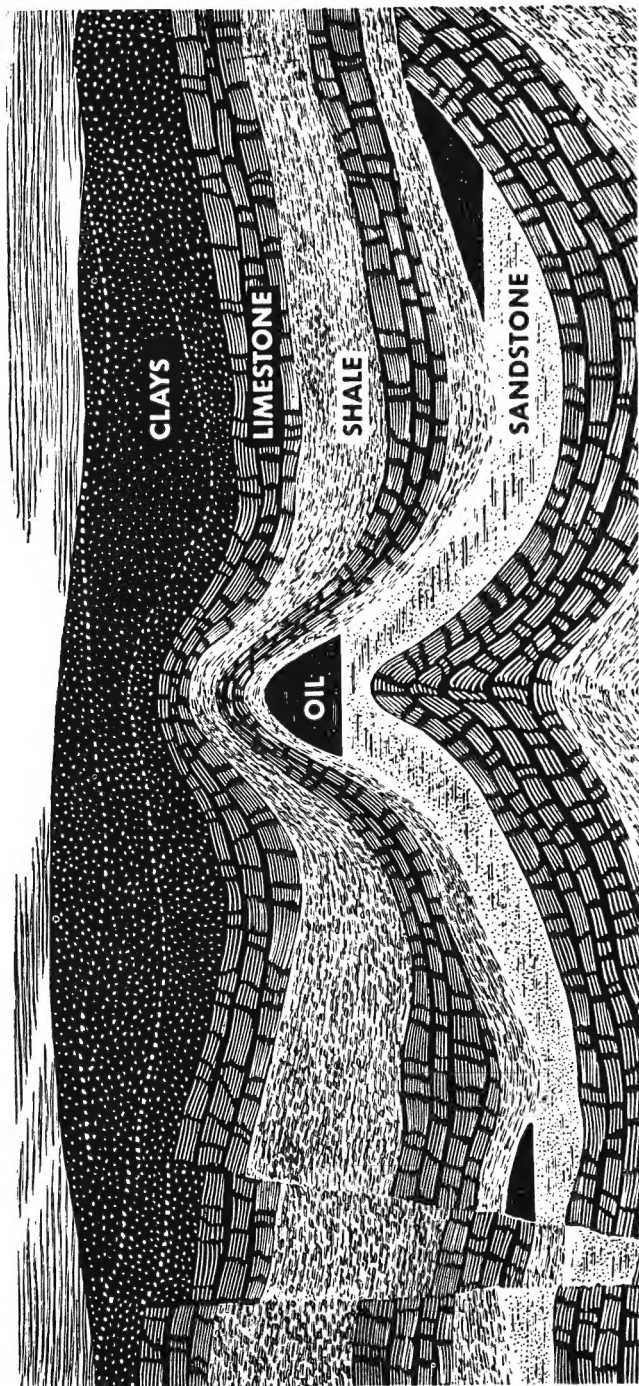
the earth, organic materials, animal and vegetable, were carried into the seas along with mineral matter. The billions of microscopic organisms that lived in the seas added their flesh and their skeletons to the muddy ooze. Some of the sediments came to contain a substantial percentage of organic matter. Seas receded with the changes in the earth's surface, and new seas advanced. The muddy sediments grew deeper — becoming eventually as much as several miles deep in some parts of our western plains.

As the sediments grew deeper, the weight of those above caused those at the bottom to compact into rocks. Sands gradually became sandstone, muds became shales, and the limy oozes became limestone. This pressure, long continued, and coupled with heat, the action of bacteria and chemical reactions, transformed the remains of organic life in these sediments into oil and natural gas

But this oil and gas did not always remain where it was formed. Being light in weight, and associated with the water squeezed out of the sediments in the process of compaction, it had a tendency to move upward through porous rock. Sometimes it reached the surface and was lost. Only where the surrounding material was so impervious that it could not escape did it become trapped and accumulate. Sometimes it would accumulate in an "anticline"—a place where the impervious sedimentary rocks above had become raised or bent to form something like an inverted bowl, and the oil and gas would be held in place by the rock above and by water in the porous sediments below. Sometimes it would accumulate against a "fault" or "trap" as indicated in the drawing on the opposite page.

Sometimes a "reef" would provide a suitable place for oil accumulation, and as our most significant oil discoveries in Western Canada have been made in reefs, a word of explanation is indicated. During the advance and recession of the ancient seas, some of the tiny creatures that inhabited those seas, finding a depth and temperature of water suitable to their continued existence, would establish a colony and would live, reproduce and die, generation after generation, in one particular place. The gradual change in the water level would eventually render the place no longer suitable and the survivors





*A stratigraphic trap*

*An anticline*

*A fault*

of the colony would migrate to a new location, they and their descendants living and dying there until the advancing or receding waters compelled some future generation again to migrate. The remains of these colonies—the accumulation of centuries of the bodies of these sea creatures, mixed with the silt deposited during the period of their existence, and covered by the sediments deposited during the succeeding millions of years—became the reefs which the oil men look for today.

Whether the oil sometimes found in these reefs came from the remains of the creatures who lived and died there, or whether it migrated to the reefs to become trapped there, is a problem on which geologists differ; but the reefs are porous, and when covered by an impervious layer of rock became ideal places for oil accumulation.

There is a popular conception that the oil accumulated in an actual pool. This is not the case. The oil may be found in porous limestone which may look much like a rigid sponge; or it may be accumulated in the tiny pore spaces of a sandstone. The lighter compounds constituting natural gas naturally migrated to the top and later in this booklet you will see how this gas drives the oil out of the holes or pores once the pressure is released.

Oil originated in Western Canada in a number of geologic periods, all of which seem to be associated with an advance or recession of an ancient sea. Devonian seas were present in this area, and the important finds of Leduc, Redwater, Golden Spike, Stettler, Excelsior and Normandville have been in Devonian sediments. Other finds—Turner Valley in particular—have been made in the Madison limestone, of a slightly later geologic age called the Mississippian, which was laid down in a sea which covered only the southern portion of the provinces of Alberta, Saskatchewan and Manitoba.

The seas of the Cretaceous period which covered the prairies some 60 to 125 million years ago were responsible for other oil accumulation and considerable gas. Lloydminster, Taber, Joseph Lake and Viking-Kinsella are examples of this

On the opposite page is a typical geological cross-section of the sediments covering the Alberta plains showing where the significant oil and gas discoveries have been made.

## TYPICAL GEOLOGICAL CROSS-SECTION IN ALBERTA

| Approximate Age   | Period        | Formation                                                                        | Description                                                                    |
|-------------------|---------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Millions of Years |               |                                                                                  |                                                                                |
| 0                 |               | <b>Surface</b>                                                                   | Sands, gravel, clay, glacial drift.                                            |
|                   | TERTIARY      | <b>Paskapoo</b>                                                                  | Continental shales and sandstones                                              |
| 58                |               | <b>Edmonton and Belly River</b>                                                  | Continental shales, sandstone, coal                                            |
|                   |               | <b>Alberta</b>                                                                   |                                                                                |
|                   |               | Gas at Medicine Hat                                                              | Marine shales local sands                                                      |
|                   |               | Gas at Viking, Bow Island, Oil at Joseph Lake                                    | Continental sands, shales, coal                                                |
|                   | CRETACEOUS    | <b>Blairmore</b>                                                                 |                                                                                |
|                   |               | Oil at Taber, Stettler, Prince, Woodbend, etc.                                   |                                                                                |
| 125               |               | <b>Fernie or Ellis</b>                                                           | Marine shales, local sandstones                                                |
| 153               | JURASSIC      | Local oil and gas—Conrad                                                         |                                                                                |
|                   |               | Gas and oil at Whitelaw in Peace River area                                      |                                                                                |
|                   | TRIASSIC      | These deposits largely missing in Alberta plains                                 |                                                                                |
|                   | PERMIAN       |                                                                                  |                                                                                |
|                   | PENNSYLVANIAN |                                                                                  |                                                                                |
| 233               |               | <b>Madison</b>                                                                   | Marine limestones and dolomites                                                |
|                   | MISSISSIPPIAN | Gas and oil at Turner Valley, Pincher Creek and Jumping Pound                    |                                                                                |
| 255               |               | <b>Potlatch</b>                                                                  | Marine, mostly anhydrite                                                       |
|                   | DEVONIAN      | D2 oil and gas, Leduc, Woodbend, Stettler, Excelsior, Duhamel, etc               |                                                                                |
|                   |               | <b>Jefferson</b>                                                                 | Marine limestone, dolomites                                                    |
|                   | SILURIAN      | D3 oil and gas Redwater, Leduc, Woodbend, Stettler, Big Valley, Acheson, Duhamel | Green shales, coral reefs                                                      |
|                   | ORDOVICIAN    |                                                                                  | Marine limestone, dolomites local shales, sandstones, salt and gypsum deposits |
| 430               |               |                                                                                  |                                                                                |
|                   | CAMBRIAN      |                                                                                  | Major unconformity or break between pre-Cambrian and Cambrian                  |
| 510               | PRECAMBRIAN   |                                                                                  | Granites, Schists, Volcanics and Sediments in pre-Cambrian                     |

## II.

# The History of Oil--Canada's Position

The use of oil in one form or another goes back at least 6,000 years. Long before the great days of Babylon the inhabitants of Kish and Ur of the Chaldees used asphalt as a mortar to hold bricks together. The Babylonians used asphalt to water-proof boats, drains, and cisterns, and made torches by dipping bundles of reeds in oil. Nebuchadnezzar used asphalt for road building. The Egyptians were familiar with asphalt, using it amongst other purposes in the preparation of bodies for burial—the well-preserved "mummies" discovered in many Egyptian tombs. The Bible contains several references to the use of oil in different forms, and there are many such references in the writings of the early Greeks

One common use of oil in early times was as a curative—a use frequently mentioned in legend and in history. The first white men on this continent found the Indians using the crude oil as a medicine and as an ointment, skimming it off the surface of springs and streams, into which it had seeped from underground reservoirs. The Indians also found these oil springs to be good hunting grounds, since wild animals came there to rid themselves of skin pests by bathing in the oil coated waters.

But old and varied as the use of oil may have been, the oil business as we know it commenced less than a hundred years ago and developed into one of the world's important industries within the past half-century.

Until the turn of the 19th century, petroleum came largely from asphalt beds, from oil springs and streams, and, sometimes, from wells dug for the purpose. During the early 1800's men began to drill for salt. Some of these salt wells encountered and were ruined by oil, and had to be abandoned. But the sperm whale, then the source of almost all lamp oil, was fast disappearing from the seas. Oil distilled from coal began to take the place of whale oil, and when it was found that crude

oil could be processed to produce the equivalent of "coal oil" at lower cost, the oil laden salt wells began to take on a new significance, and men began to drill for the express purpose of finding oil, using the techniques that had been developed by the brine well operators.

The first producing oil well on the North American Continent was opened in Lambton County, Ontario in 1858. In the following year the much publicized Drake well near Titusville, Pennsylvania, was drilled and came into production. Drilling for oil then proceeded at a rapid pace and within a few years hundreds of wells had been drilled, many refineries had been established, and the oil business began to take its place as a recognized industry.

Strange as it may seem to us now, gasoline was for a long time a useless by-product which was thrown away. Not until 1892 when Charles Duryea developed a gasoline powered motor car was any use found for that particular by-product, and it was not until 1910 that the demand for gasoline exceeded the demand for kerosine. It was of course the internal combustion engine and particularly its use in motor vehicles that caused the development of the oil industry to its present stage.

Today petroleum and petroleum products play a part in almost every human activity and have virtually created our present way of life. Lubricating oils and petroleum fuels have made possible the high speed, mass production machinery which produces the great quantities of materials we now consume. Thanks largely to the oil industry's lubricants and fuels, man and his animals do only a small part of this nation's physical labor. Machinery, much of it powered by petroleum fuels, does the rest. This means greater productivity and more leisure for man—in short, a better standard of living. Asphalt, a petroleum product, has meant good roads, and these, opening most of the country to travel and the flow of products, have added their share to the comfort and convenience of life. Hundreds of every-day products are made, in whole or part, from petroleum. Medicines, fertilizers, insecticides, cosmetics, plastics, textiles, paints and varnishes,, solvents, inks, detergents, dentifrices, carpets, linoleum, rubber compounds, glycerine and alcohol are only a few of the commodities in the manufacture of which the oil industry plays a part.

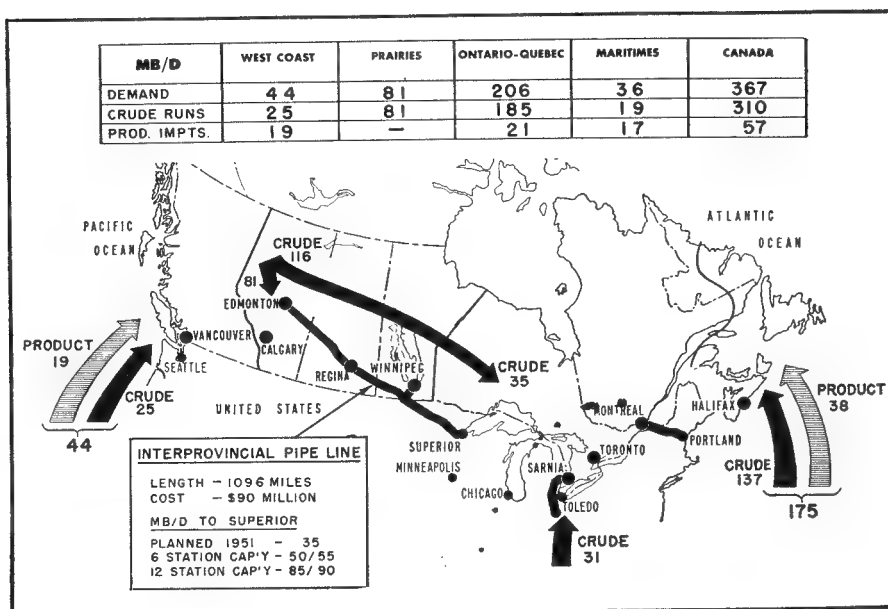
The diagram is a tree structure representing the refining of crude oil. The central trunk is labeled 'CRUDE OIL'. The main branches and their sub-products are as follows:

- GASES**
  - ETHANE
  - PROPANE
  - BUTANE
  - PENTANE
  - HEXANE
  - HEPTANE
  - OCTANE
  - NONANE
  - DECANE
  - UNDECANE
  - DODECANE
  - TRIDECANE
  - TETRADECANE
  - PENTADECANE
  - HEXADECANE
  - HEPTADECANE
  - OCTADECANE
  - NONADECANE
  - ICOSANE
  - TRICOSANE
  - TETRACOSANE
  - PENTACOSANE
  - HEXACOSANE
  - HEPTACOSANE
  - OCTACOSANE
  - NONACOSANE
  - TRIACONTANE
  - TETRACONTANE
  - PENTACONTANE
  - HEXACONTANE
  - HEPTACONTANE
  - OCTACONTANE
  - NONACONTANE
  - TRIACONTANE
  - TETRACONTANE
  - PENTACONTANE
  - HEXACONTANE
  - HEPTACONTANE
  - OCTACONTANE
  - NONACONTANE
- NAPHTHAS**
  - 1,2-DIMETHYLBENZENE
  - 1,3-DIMETHYLBENZENE
  - 1,4-DIMETHYLBENZENE
  - 1,2,3-TRIMETHYLBENZENE
  - 1,2,4-TRIMETHYLBENZENE
  - 1,3,5-TRIMETHYLBENZENE
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12

totalling over 100 million barrels and gas in excess of 1500 billion cubic feet, but its production, with that of the other Canadian fields, fell far short of meeting our demand. In 1947, the year of Leduc's discovery, Canada consumed about 100 million barrels of oil. It produced in that year less than 7½ million barrels.

Many millions of dollars were spent on oil exploration during the years between Turner Valley and Leduc, but results were most disheartening. Some oil was found, and considerable gas, but no significant oil pool was discovered. Many companies became discouraged and retired from Western Canada. Leduc, of course, changed all of that. Men, machines and a great deal of money poured into the West, exploration proceeded at a greatly accelerated pace, several important pools were found in rapid succession, and a substantial Canadian oil producing industry was established.



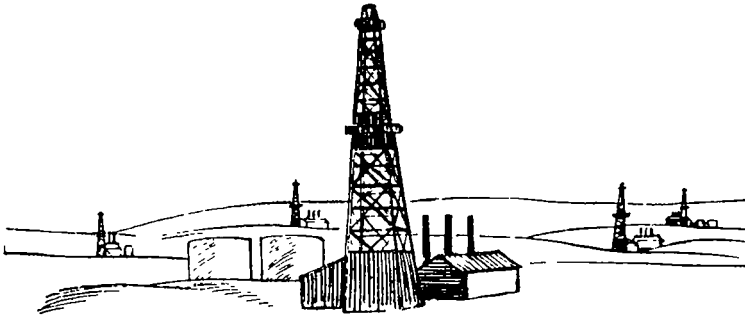
*How Canada's oil requirements will be met in 1951  
 All figures represent thousands of barrels per day.*

As this is written Canada is still far from self-sufficient in oil, having a potential production of about half her demand. But the rate of drilling and the extent of exploration give promise that theoretical self-sufficiency may not be too many

years distant—theoretical, because if export markets can be developed equal to Canada's imports we will have achieved the equivalent of self-sufficiency and it may be more economical to follow this course. As this is written the West is supplying the entire demand of the prairie provinces, and the pipeline to Lake Superior will eventually enable most of the Ontario market and some of the Midwest American market to be supplied from Western Canadian sources. This with the prairie market should absorb about all of our present potential production. The competitive position of foreign oils and the high cost of transportation bar us for the time being from other possible Canadian—and foreign—markets, but these problems should eventually be overcome.

In the meantime the search for oil goes on, so that if and when additional markets are secured we will have the reserves and the productive capacity available to serve them.

Let us now see how men look for oil.





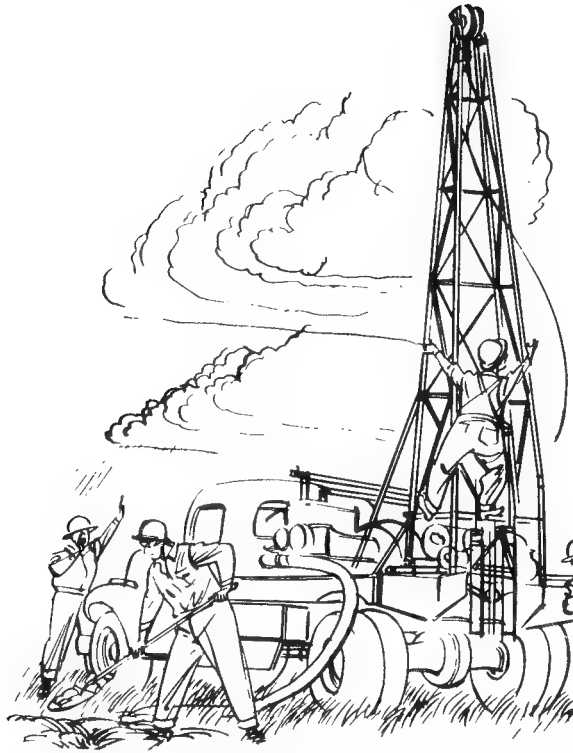
## Exploring for Oil

Oil bearing reefs and structures are, of course, most difficult to find. They occupy at best only a minute fraction of the area of the Prairie Provinces and they may lie anywhere from a few hundred feet to several miles below the surface. They may be almost any size or shape. Finding them is, literally, like finding a needle in a haystack. There are, of course, some scientific aids, but none of these can do more than locate some abnormality in the sub-structure of the earth, indicating a possible condition favorable for the accumulation of oil. The only way to tell for sure whether oil is present is to drill a well or a series of wells

The search for oil starts with the field geologist. He looks for clues in the deep canyons and gullies which rivers and streams have formed, for they sometimes expose the layers of rock laid down by the ancient seas. He can see how the layers are sloping, which is important because he is always looking for rock formations which may have trapped oil. The presence or absence in the rock of the shells and bones of tiny sea creatures also tell him something of the conditions existing when the rock layers were laid down. He studies the plains and foothills on the ground and from the air, and, adding his clues to those collected by others whose functions are described in the following paragraphs, he hopes to determine that in a particular location millions of years ago conditions were favorable for the accumulation of oil.

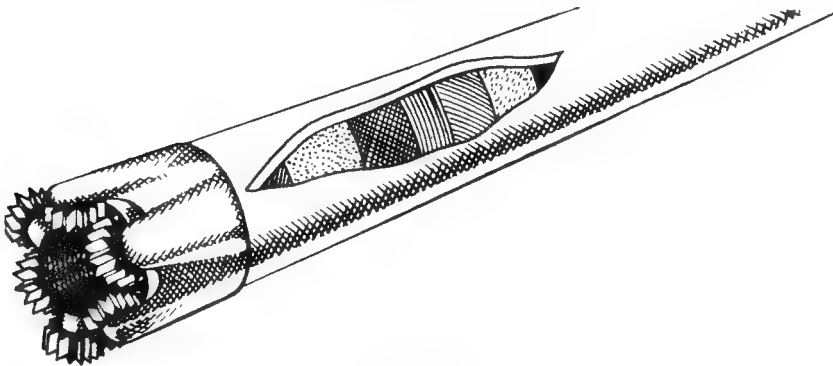
Of course only a sketchy picture may be obtained from surface signs—even in the deep canyons and gullies—of what may lie far below, so to aid the geologist in his task, other experts are called upon.

The core driller is one of these. He uses a portable drilling rig mounted on a large truck. When his drill reaches the sediments below the top layers of soil, he uses a special drilling bit, hollow in the centre, which cuts cores out of the rock and brings them to the surface. These are studied by the geologist and from them he obtains much the same type of information that he gathers in other areas from the out-



*A portable  
core-drill*

cropping of rocks in the gullies and canyons. But the core driller may bore hundreds of feet into the earth and on the plains there are few canyons or gullies which furnish information on rock layers that deep. Little by little the picture begins to take shape but still the evidence relates only to rock layers above most of the oil producing horizons.



*A core-bit*

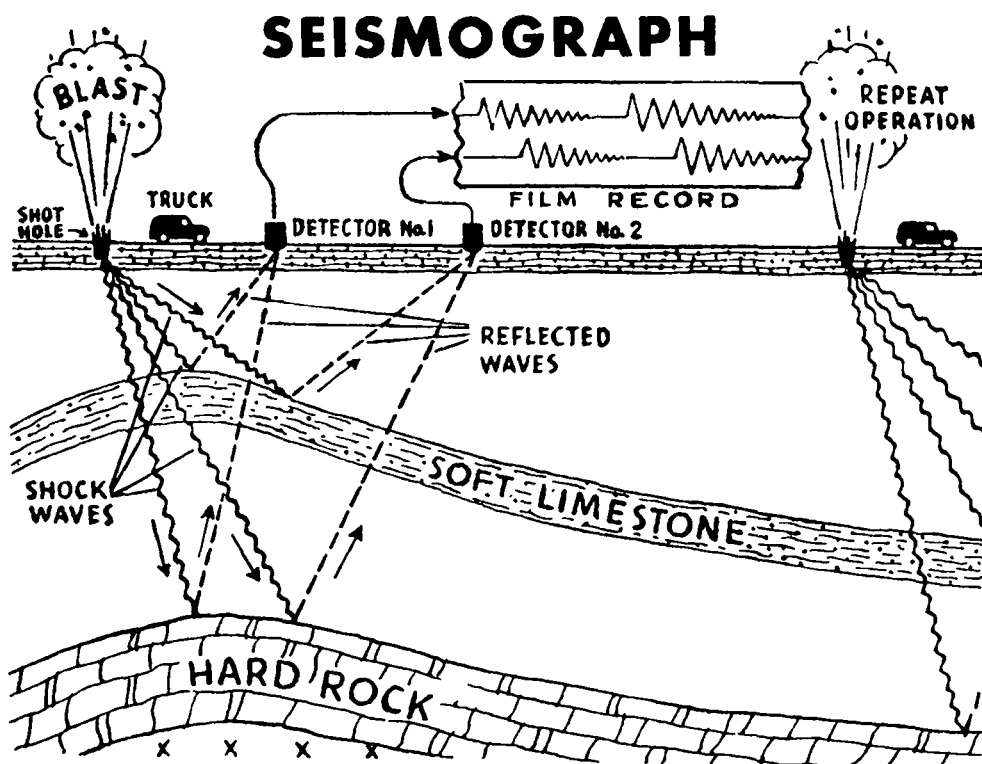
To test deeper formations, the oil explorer resorts to deduction from information obtained in a variety of ways, and from a variety of instruments. These instruments are operated by the geophysicists—the men who apply the science of geophysics to the science of geology.

The instrument most commonly used in Western Canada is the seismograph. It is much like the instrument that is used to measure the forces of earthquakes, and about which we read frequently in the daily press. The average seismograph crew numbers some twenty or thirty men, includes a truck on which is mounted a light portable drilling rig, similar to a core drill, a water truck to supply the rig, a dynamite truck to carry explosives, and an instrument truck carrying seismograph instruments and recording devices. Also in rough country distant from settlements, it may include a bulldozer for opening roads, and trailers for housing, cooking, and for an office. It costs, incidentally, up to \$40,000 each month to keep a single seismograph crew in the field, and one crew may take many months to test adequately a single locality.

The seismograph crew drills shotholes thirty to sixty feet into the earth and explodes dynamite charges in these holes. These explosions cause shock waves to travel downwards, bouncing back to the surface from underground rock layers.

*Firing a  
shot in  
seismic  
exploration*





*Soft formations reflect weakly on the recording film and hard formations make larger "jogs." The elapsed time between the blast and the return of the shock waves to the detectors gives an indication of the depth of the formations.*

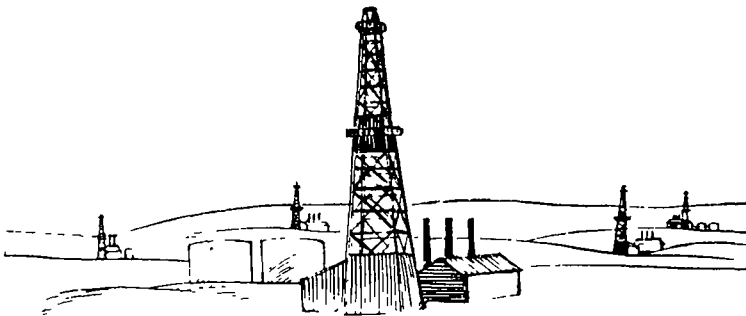
The time it takes for them to bounce back is measured in thousandths of a second, and recorded in the instrument truck. The depth of the rock from which they bounce back is thereby estimated. In this way oil men have learned something of the shape of the underground rock layers and may thus locate the reefs or structures they are seeking.

To be effective shots should be fired at frequent intervals. The sub-surface "anomalies" indicating even large oilfields like Leduc, Redwater and more particularly Golden Spike, each occupy such a small area that any one of them might easily be missed by a seismograph party making only a general survey of the locality.

Another scientific aid in general use is the "gravity meter" which records very small variations in the gravity or "pull" of the earth and so, when the information is interpreted may give some indication of the shape of the rock structures far below the surface

Another aid is the "magnetometer" which indicates slight variations in the earth's magnetism at different points and may help to give some clue as to what lies below the surface.

When the results of the geologist's work have been studied and have been correlated with the interpreted evidence secured by the geophysicists, a decision must be reached as to whether deep drilling is warranted. This is a very important decision. A single exploratory well may cost as much as a million dollars, and, in Western Canada to the time this is written, only about one well out of twenty drilled in unproven territory has been a producer, even after careful study of the geological and geophysical evidence. Yet, the only way to test that evidence is to drill.



#### IV.

## Oil Rights and Surface Rights

Usually, but not always, some protection on oil rights in the area is secured before the commencement of geophysical exploration. This is not strictly necessary, however, as geophysical crews may use the road allowances for this work, subject to regulations made for the protection of the highways and adjacent private property.

But before an oil company commences the drilling of an exploratory well, it must have some control over the oil rights on a substantial block of acreage surrounding the proposed well site. The odds are greatly against the discovery of oil in any exploratory well, and if a company is to incur the heavy cost of drilling, and assume the risk of failure, it requires sufficient oil lands so that if a discovery is made, it will show a profit after taking care of possibly 20 or more failures. Drilling on a single quarter-section or even a section is never warranted unless the acreage has been proved or partially proved by a producing well nearby.

Who owns these oil rights, and how are they acquired? To answer this requires a brief journey into Western Canadian history.

Under the charter granted by Charles II in 1670 by which the Hudson's Bay Company explored and opened up the northern half of this continent, that company was given control of practically all of the land in the western plains. Some 200 years later when the company ceded its rights and properties to Canada, it reserved its trading posts, its right to trade, and the right to select certain lands out of new areas as and when they were thrown open for settlement. Generally this amounted to 1/20 of each township—in most cases section 8 and three-quarters of section 26 in each township—between the U.S. boundary and the North Saskatchewan River. As a result of exchanges the "Bay" now holds considerable land north of that river.

As one of the conditions of the construction of the railway which was so necessary to the continued existence and develop-

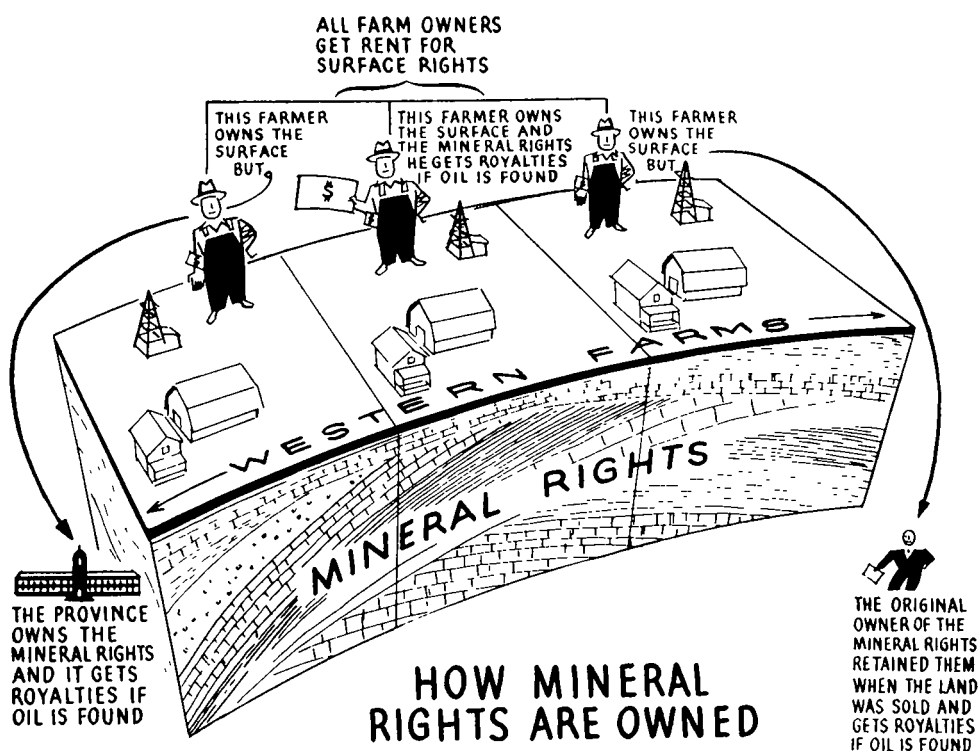
ment of Canada, the Canadian government in 1881 granted to the C.P.R. all of the odd numbered sections except sections 11 and 29 in each township for a distance of 25 miles on each side of the main line of the railway—the so-called "railway belt." As a result of exchange of lands this pattern, like that of the Hudson's Bay Company did not remain constant.

Other railways were built, and some of them also received grants of land as a condition of their construction.

In all of these cases, minerals and surface were granted together. In fact nobody seems to have considered separate treatment of minerals in those early days. The government of Canada granted minerals with the surface of all lands homesteaded in the early days of the West, and for a number of years the railway companies and the "Bay" when disposing of their lands sold the minerals along with the surface. But in 1887 the Canadian government commenced to reserve minerals out of homestead grants, and sometime later the Hudson's Bay Company and the railways adopted the same procedure, at first reserving certain minerals only, and later reserving them all.

In 1930, the natural resources of the western plains were transferred from the Canadian Government to the Provinces and the latter became the owner of the mines and minerals theretofore vested in Canada, except those in the National Parks.

As matters stand at present, therefore, about the only cases where surface owners also own the oil rights are where lands were homesteaded prior to 1887, or where lands were purchased from the Hudson's Bay Company, or the C.P.R. or some other railway land company during the years when it was their practice to sell those rights with the surface. Even in such cases, some intervening owner, on disposing of his land, may have reserved those rights to himself. As a result, relatively few western farmers own the oil and gas underlying their lands. It is estimated that in the case of Alberta, only about 7% of the minerals are in private hands, and this 7% includes the holdings of the "Bay," the C.P.R. and the other railway land companies. It is about the same, or even less, in British Columbia. The percentage of privately



owned minerals is somewhat higher in Saskatchewan and much higher in Manitoba because those Provinces were settled at an earlier date

So, the chances are that the oil company will have to go to the Provincial Government to obtain the right to explore or drill for oil. Regulations governing the leasing of Crown lands vary from province to province, but, since most of the development to date has taken place in Alberta, it might be of interest to outline here how oil and gas rights belonging to that Province are handled

In Alberta, as this is written, the first step is usually the acquiring of a reservation or reservations, generally of 100,000 acres each. Each reservation is granted for a nominal fee and a substantial performance deposit, which is returned if an active exploration program is carried out. While work is being conducted, a reservation may be held for one year with no consideration other than the initial application fee. In the



second year, and providing exploration continues, a reservation may be held for successive three month periods at rentals totalling for the year 30c per acre. In the third year, providing drilling has been commenced prior thereto, the reservation may be held for successive three month periods by payments totaling 70c per acre for the year.

If the results of the exploration and drilling warrant it, the company may at any time before the end of the third year, and must, if commercial oil production is encountered prior to that time, convert its reservation into leases. On conversion the holder of the reservation is permitted to lease up to 50% of the reservation at an annual rental of \$1.00 per acre and subject to a royalty payable to the Province of 12½% of the total production or, at the lessee's option, to a sliding scale of royalty ranging from 5 to 15% depending on the daily average production of each well.

When leases are taken out of a reservation, each lease must be not more than 3x3 miles or 2x4 miles in extent and must be not more than twice as long as it is wide. Leases must be taken in checkerboard pattern, touching only at the corners and lease boundaries must be apart from one another a distance of not less than one mile. One half of the money spent on the reservation in test drilling or other exploratory work will apply as a credit on the first year's rental on the leases taken.

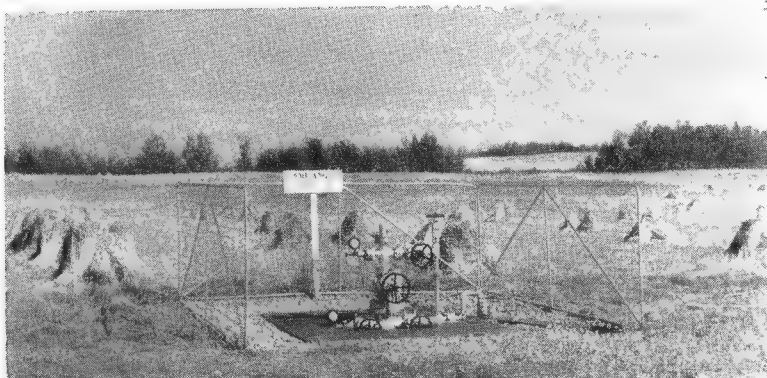
The areas reverting to the Province out of a reservation become Crown reserves and the right to lease them subject to royalty may be later offered for sale by sealed tender. This sometimes results in large sums of money being paid into the Provincial Treasury. Some sales of Redwater acreage have realized as much as \$1,800,000 for a single quarter section.

This policy is a reasonably satisfactory one for all concerned. Oil companies prepared to risk large sums of money in geophysical work and exploratory drilling are given sufficient acreage at relatively low cost to guarantee them a fair return if they happen to be successful. The people, through their government, by reserving at least half of the acreage scattered throughout each reservation, are reasonably sure of sharing in the results of successful drilling conducted at no financial risk to themselves, and that they have done so is indicated by the fact that in 1950 the Province

of Alberta, from the sale of Crown reserves alone, realized \$36,000,000 in addition to reservation fees and extension fees, lease rentals, and royalties. On the other hand, operators who do not wish to risk their capital in wildcat drilling have an opportunity to buy from the government the right to lease acreage proved or semi-proved by the expenditures of the original reservation holder.

The reservation of minerals to the Crown, the C.P.R., the Hudson's Bay Company, or to anyone else, carried with it the right, on payment of compensation to the surface owner, to enter upon the surface to the extent necessary to extract the minerals. The amount payable for this privilege is usually settled by agreement but if agreement cannot be reached, the amount is ascertained by the Courts, or by arbitration — in Alberta by the Right of Entry Arbitration Board.

Compensation for surface use is usually on a more generous scale than that paid for land taken for railways, roads, or other purposes, being generally well in excess of the market value of the land. An initial payment and annual rentals are paid for about four acres for each well site and for the area required for access roads, although once a well is placed on production, most of the four acres may still be used for farming. While surface rentals may seem small in comparison to the total costs of exploration and drilling, they form an important item in the cost of operation of a producing well, and have a direct effect on the length of time the well may be operated economically.



*This indicates the space occupied by a producing well in an Alberta grain field.*

## Drilling for Oil

As a result of months of geological and geophysical exploration, let us assume that the oil company has located what might be an oil bearing reef or structure, it has acquired sufficient acreage to make the risk of drilling worth while, it has made the necessary arrangement with the surface owner and has decided to put down a well. In some cases the company may have its own drilling "rig," but more commonly it will engage the services of a drilling contractor—a firm owning one or several rigs and which drills oil wells for others on a contract basis

First a site must be chosen. Here a number of factors must be considered, the geological evidence as to the assumed location of the reef or structure, the availability of water, the ease of access to the site for men and machines, and it must be located in compliance with the government regulations concerning well spacing.

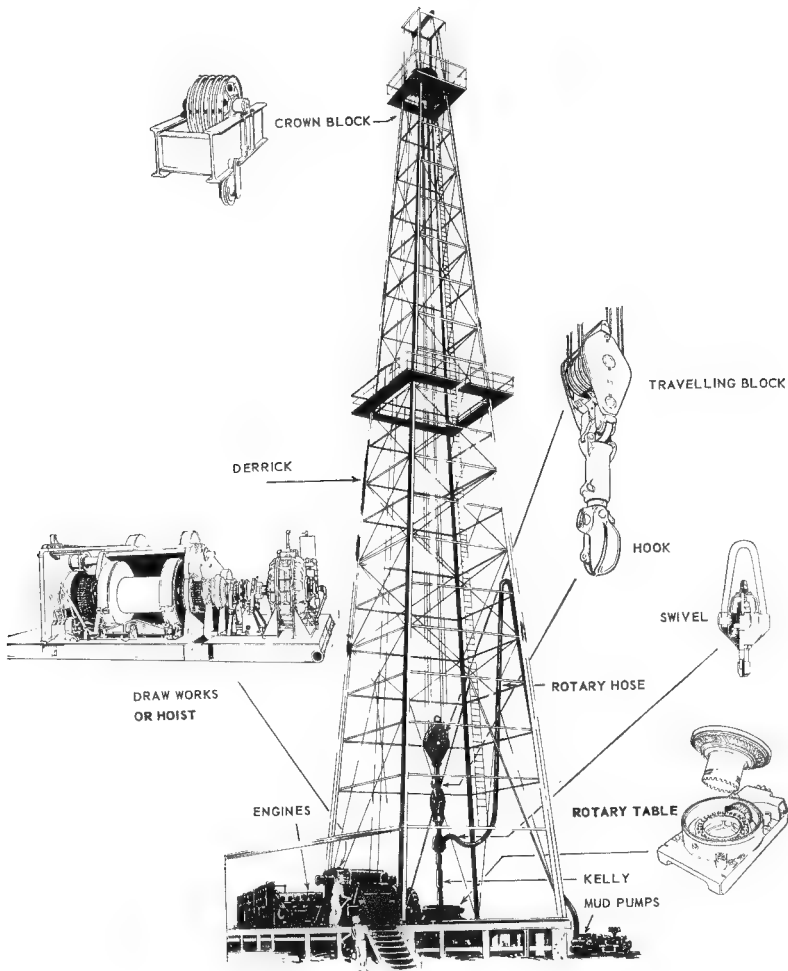
Next a water supply must be developed, a road must be built, a well cellar must be dug to make room for the necessary valves and fittings. Timbers or concrete blocks must be installed as supports for the derrick and the drilling machinery, and if a "rotary rig" is to be used, a mud pit must be dug and diked. Not until then, may the rig be moved onto the location and the drilling commence.

Drilling rigs may be either "cable tool rigs" which drill by alternately raising and dropping a heavy tool bit suspended from a pulley or crown block at the top of the derrick, or rotary rigs which use the principle of the auger, and bore into the ground. Each type has its advantages and disadvantages, but as the rotary rig is in almost universal use in Western Canada, we shall deal with that type exclusively in this booklet.

The commanding structure that graces the skyline and signifies drilling activity may be a derrick, but for reasonably shallow drilling in some parts of western Canada is more likely to be a "mast." The only difference, apart from a slight difference in appearance, is that the mast comes in two or

three sections and is easier to erect and dismantle. The derrick or mast will be from 90 to 140 feet in height, depending on the formation to be penetrated and the depth of the proposed drilling.

In the middle of the derrick floor is the "rotary table," which transmits the power to rotate the drill pipe, at the end of which is the "bit." It in turn is rotated through a chain drive from the hoist or "draw works," which also raises and lowers the drill pipe and casing. The draw works operate



*A Rotary Drilling Rig.*

through a driving mechanism from the engine which may be steam powered but in most rigs presently in use on the plains, is diesel powered.

A removable bushing in the centre of the rotary table grips the "kelly"—a square steel bar 4 to 6 inches through and 40 to 50 feet long which has couplings attaching it to the drill pipe below. Attached to the top of the kelly is the swivel." It hangs by a hook from a huge pulley called the "travelling block" which is suspended on cables from the stationary "crown block" at the top of the derrick. The cable in turn winds on the drums of the draw works so that by raising or lowering the travelling block the kelly, drill pipe, and drill bit can be raised or lowered.

The swivel is just what its name implies. The upper part, fastened to the travelling block is stationary, the lower part turns with the kelly and the rotary table. Sticking out at the side of the stationary portion of the swivel is a heavy hose, which furnishes "drilling mud" to the drill bit through the hollow kelly and drill pipe.

Whenever a bit needs to be changed, the rotary table is stopped, the bushing removed, the "string of pipe" is raised until the kelly can be unscrewed from the drill pipe, and the kelly, with swivel attached, is stuck in a slanting hole in the ground known as the "rat hole," and unhooked from the

*"Rough-  
necks"  
breaking  
drill pipe  
in order  
to add  
another  
length.*



travelling block. Then the travelling block is attached to the drill pipe, and the pipe is raised and unscrewed in sections of one or several lengths depending on the height of the derrick, the pipe still in the well being held meanwhile by "slips" inserted in the rotary table and gripping the top length of pipe under its collar. The pipe sections withdrawn are stacked on one side of the derrick, and from the last joint the bit is unscrewed and replaced. The operation is then reversed; the length of pipe with the new drill bit is lowered; section by section the balance of the drill pipe is screwed together and lowered into the well with a new length if necessary; the kelly and swivel are hooked to the travelling block, withdrawn from the rat hole and screwed to the drill pipe; and the whole is lowered until the bit touches the bottom of the hole. The bushing is then put in, the mud pumps are started, the driller throws some levers engaging the rotary table, and drilling commences.

"Rock" bits, with rolling serrated or toothed cones, are of many designs depending on the formation to be penetrated, and in one form or another are the kind most commonly used in



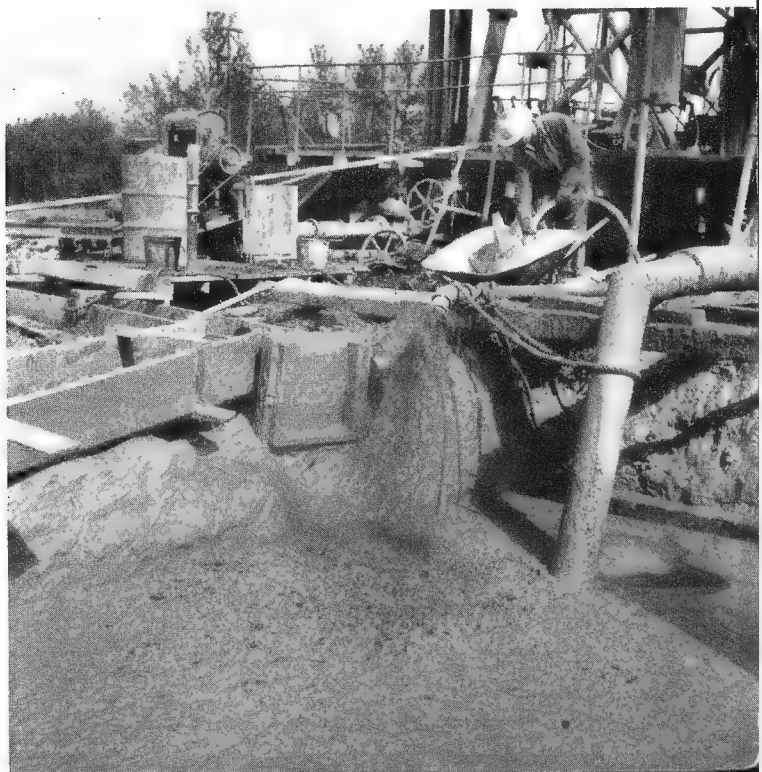
*Drilling  
bits worn  
out in  
drilling a  
Redwater  
well.*

hard formations, although when going through soil and soft rock, a "fish-tail" bit may be used. Bits cost \$150 to \$200 each, and when extremely hard formations are encountered may be completely worn out after only a few feet of drilling. Normally, about thirty bits will be used in drilling a 5,000-foot well on the western plains.

Drilling mud, used only in rotary drilling, furnishes the lubricant for the bit, helps keep it cool, flushes out all cuttings, and helps keep the well under control if gas or oil is encountered. The latter, one of the principal functions of mud, is accomplished in two ways. The mud plasters the wall of the hole, which helps to prevent cave-ins, but also assists in sealing off gas, oil and water. The weight of the column of mud also helps to prevent gas or oil from blowing out of the hole. Mud must be kept at the right consistency to do the job. If there is no gas or water in the well to be overcome, the mud will be light; but if a high pressure gas sand has been encountered, it will be heavy.

The action of the mud in plastering the wall of the hole may be so effective as to seal off oil or gas producing strata making

*The mud  
Pit at a  
rotary  
drilling  
site.*



it difficult to bring the well into production. To avoid sealing off a pay horizon, oil is sometimes used in or with the mud. The type of mud used depends on the circumstances of each case, and the selection of the right mud is an important function of the mud engineer.

A couple of "slush pumps" take the mud from the mud pit and pump it, under several hundred pounds pressure through the hose to the swivel, and thence through the hollow kelly and drill pipe to the bottom of the well where it emerges through the bit. After emerging, the mud circulates to the top of the well between the drill pipe and the wall of the hole and goes back to the mud pit over a "shaker" which sifts out the cuttings from the drill bit and lets the geologist know the type of formation then being penetrated. From this he can judge with some degree of accuracy at what depth the possible oil and gas horizons should be encountered.

From time to time, particularly in a wildcat or exploratory well a core will be taken so that the geologist may examine it and ascertain with greater accuracy the formation being drilled and its oil possibilities. "Coring" may be done by pulling the drill pipe and substituting for the regular bit a core bit—a steel tube with diamond chips or cutters of special steel around the bottom edge. When this is rotated, the tube becomes filled with a core of the rock being penetrated which can be withdrawn for examination. This procedure however necessitates the changing of the bit before and after the coring operations, and is costly due to the time consumed in twice withdrawing and running back the drill pipe. To avoid this a wire line core barrel is often used. This fits inside a larger bit, and when the core has been taken it can be withdrawn by a small cable through the hollow drill stem without unnecessarily delaying the drilling operation.

One method of checking on the progress of drilling that is used on all drilling rigs is the weight indicator. This measures the pressure of the bit on the bottom of the hole. As some formations can be drilled faster than others, a careful watch on drilling time, correlated with the weight indicator readings, gives a good idea of the character of the formation being drilled.



Another aid in this direction is the "electrolog." This may be taken during drilling, but is almost invariably taken after a hole is completed. An electrode is lowered into the hole, an electric current is sent through the formation and back to the well head, and the resistance encountered by the current is measured and recorded. Different rock strata have different resistances so some idea of the formation can thus be obtained. "Radioactivity logging" is also of assistance. In this procedure, neutron and gamma rays bombard the formation from a similar electrode and are recorded in similar manner at the surface, showing the hydrogen content of the formation and indicating whether it should be tested further.

All operators are anxious to keep their wells straight unless for some reason it is desired to drill a "directional" hole. For this reason wells are surveyed occasionally to determine the deviation from the vertical. If a well is found to have deviated unduly (and government regulations require a minimum of deviation) it can be brought back to the vertical by the use of a "whipstock," a beveled bar of steel which is lowered into the hole to the point where deviation is required and which diverts the drill pipe in the direction desired. The same procedure is used when directional drilling is desired, as was the case when in 1948 the "wild" well, Atlantic No. 3 in the Leduc field, was brought under control by being tapped far underground by two holes drilled directionally from points some distance away.

When a well is drilled into a zone from which production may be expected, a "drill stem test" is usually taken. In such a test, the drill pipe is run into the hole equipped with a tester on the bottom of the pipe. A packer seals the pipe against the wall of the hole, holding out the mud, and a valve permits gas, oil and water from the zone to flow into the drill pipe. The rate of potential production is estimated from the height to which oil rises in the pipe within a given time.

Not infrequently, particularly in deep wells and where faults and upended rock strata are encountered, a bit will become stuck and the drill pipe will break. This necessitates a "fishing job" and for this purpose a variety of strange tools have been devised, each for its special circumstances. Sometimes none of these will attach to or pull out the stuck bit or drill pipe and the driller will have to resort to directional drilling to drill around the object, or abandon the well.

- We sometimes hear that a particular well has "lost circulation." This means that a very porous low pressure horizon has been encountered which drains away the drilling mud. In such cases all manner of materials — shavings, sawdust, feathers, straw and almost anything that will go down the well is pumped and poured in, in an attempt to plug the cavity encountered so that drilling may proceed.

In wildcat drilling where no significant water, gas or oil bearing strata are encountered, it is not usual to "set casing" except surface casing which is generally required by law to be set in the top 300 to 600 feet. But where too much water is encountered, or a gas or oil sand of non-commercial proportions has to be drilled through to reach a more important zone below, or there is danger of a cave-in, and in all cases where proven territory is being drilled and production is virtually a certainty, casing is run. Casing is steel pipe, larger and lighter in weight than drill pipe, which comes in lengths of 30 to 40 feet. The joints are threaded at each end and are screwed together and lowered into the hole like drill pipe until the bottom of the hole is reached or such higher point where it is to be "set." Usually it will be set by cementing—by filling in with cement the space between it and the wall of the hole. This is done by pumping into the casing the amount of cement required to do the job, by placing on top of the cement a wooden plug and by forcing water or mud under pressure into the casing. The pressure on the plug forces the cement down the casing, and up between the casing and the wall of the hole. Pressure is kept on until the cement sets, after which the plug and balance of the cement are drilled through and drilling proceeds.

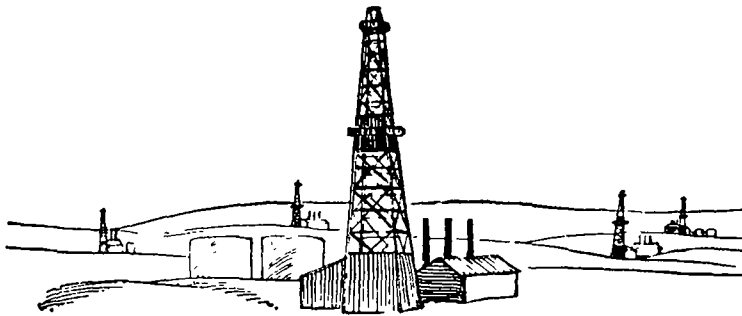
Well surveying, drill stem testing, electro-logging, radio-activity logging, and cementing are operations usually performed by independent servicing concerns making a specialty of a particular operation.

Once a "string" of casing has been set, the size of the hole has to be reduced for further drilling. A reduction in size must be made each time casing is set, since each new string must be lowered inside the casing already in place. To allow for this the driller, even in comparatively shallow wells like

most of those drilled on the plains, will start with a 13 $\frac{3}{4}$ -inch hole so that he can finish with at least a 5 $\frac{1}{2}$ -inch string

At all times after surface casing is set, drilling proceeds with a blow-out preventer in place. This is a heavy fitting, fastened to the top of the casing, by which the driller can simply and quickly close off the hole. This will prevent gas, which may be suddenly encountered under high pressure, from blowing out of the hole and endangering the lives of the drilling crew.

Let us assume that no difficulties are encountered, and tests indicate that the company has an oil well. Then the next step is to "bring in" the well.



## VI.

### "Bringing In" an Oil Well

We all visualize a well coming in as a gusher, spewing oil over the derrick and the surrounding landscape. Barring accidents, this no longer happens. The modern operator brings in the well under complete control. As soon as it appears that the well will likely be a producer, preparations are made to control the initial flow. Casing is run to the top of the horizon of expected production and is cemented in place. The surplus cement is then drilled out, the well is cleaned by circulating mud and water, and "tubing" is run to the producing horizon, this being a smaller string of pipe, 2 to 4 inches in diameter, run into the well inside the casing, and being the pipe through which the well produces. The production head — the "Christmas tree," we so often hear about — is in place. This is a complicated piece of equipment with several valves and gauges enabling the testing of pressures and the



*A production head  
or "Christmas tree"*

diversion of the flow to the point desired, but still permitting operation of tools in the well. Storage facilities and field lines are prepared. Mud is still circulating in the well. When all is ready the column of mud is lightened, often by displacing the mud with water, the water with oil. A "swab" acting like the piston of a pump, is run down the tubing and pulled up, bringing with it the mud, water or dead oil and permitting the gassified oil to flow into the well from the surrounding porous rock. When the flow starts, the Christmas tree diverts the flow through a pipe leading over the "flare pit" where the initial production is burned until the well is cleared of any remaining mud and clean oil is being produced. The flow is then directed into the "flow lines" and through them to the separator, and to storage.

Sometimes the casing is run to the bottom of the producing horizon and cemented into place there. In such case, the casing is perforated at the point of expected production. A perforating gun containing a number of bullets arranged at intervals around its circumference is lowered into the hole and these bullets are fired by means of an electrical charge. They literally shoot holes in the casing, permitting the oil to flow in.

When production is not as much as expected, it may be due to the sand or limestone not being sufficiently porous where the drill has reached it. If the producing horizon is limestone, this may sometimes be overcome by acidizing. Hydrochloric acid, pumped in under pressure may dissolve out passages to the more porous limestone adjacent to the well. If the reservoir rock is sandstone, a charge of nitroglycerine, lowered into the well and fired electrically, will sometimes shatter the wall of the hole and open the way to the reservoir.

Gun perforating, acidizing and shooting are also specialized operations usually handled by independent "service companies."

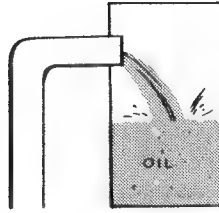
## VII.

### Producing an Oil Well

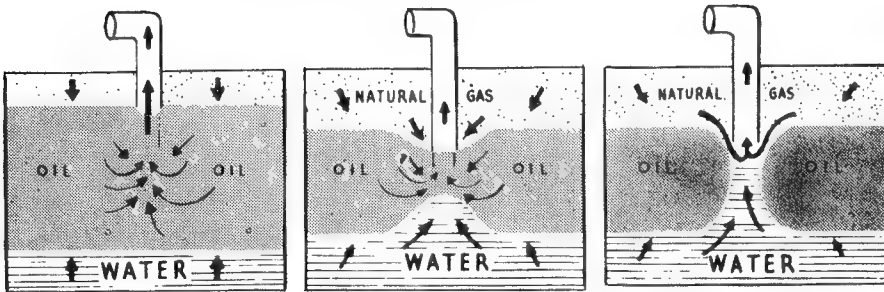
At one time, the practice was to drain a field as rapidly as possible. Usually there were many wells, owned by different companies, all tapping the same underground reservoir, and each operator was anxious to get all the oil possible out of his well lest his neighbor might drain the area under his acreage. Finally realizing that more oil can ultimately be recovered from the reservoir by less hasty production methods, for reasons illustrated on the opposite page, operators partly by mutual agreement, and assisted in most places by conservation legislation, now produce their wells in a more orderly and efficient manner. But at most only 25% to 75% of the oil is recovered. The rest stays in place, adhering to the limestone or sand, stripped of its gas content and lacking the force to move into the well.

Since oil is contained in the voids or pores in the reservoir bed of limestone or sandstone, it is obvious that some force is required to bring it to the surface. When it flows freely from a well, the output is called "flowing production." This flow may be the result of water pressure or gas pressure, or a combination of the two. Most oil pools are surrounded and underlain by water under pressure. This may represent a "hydrostatic head" of water entering the reservoir bed at a higher elevation, or may be caused by the overlying rocks themselves compacting the reservoir bed and exerting pressure on the water. If a well is drilled into sandstone in which oil under pressure is surrounded by water under the same pressure, as oil is removed, the pressure is lowered, water drives more oil into the well, and so on until the water itself reaches the well.

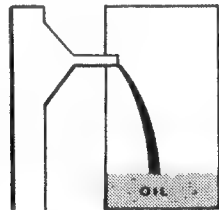
Oil in most fields contains gas in solution. In many cases, the gas volume is so great that it is not all dissolved in the oil, and the surplus, being lighter, occupies the top of the structure, above the oil. The gas is under pressure from the same causes that exert pressure on the water or the oil. When a well is drilled into the oil-bearing part of a pool, oil and gas are released and removed. This lowers the pressure in the reservoir



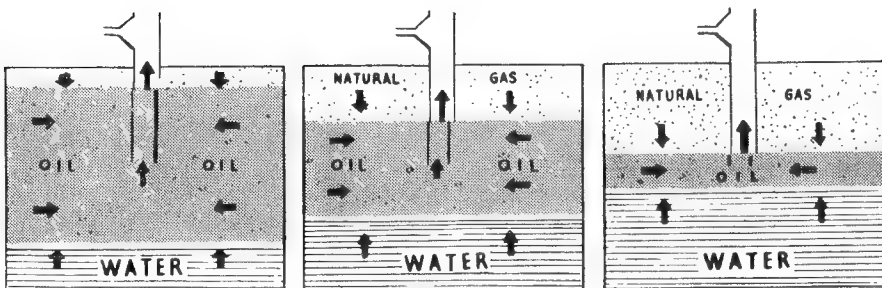
## WASTEFUL PRODUCTION



*Uncontrolled oil production is very wasteful*



## EFFICIENT PRODUCTION



*Restricting the flow increases ultimate yield*

and oil and gas move in from the surrounding area to the point of lower pressure. As long as the "bottom-hole pressure" is above that at which gas comes out of solution, the oil will retain its mobility, but if the well is allowed to produce too rapidly, the pressure drops below that required to keep the gas in solution, the gas will escape, the oil will increase in viscosity and will become less mobile, and much of it will be unrecoverable.

Once the pressure at the bottom of the well becomes less than the weight of the well-full of oil, the well must be put "on the pump." Some must be pumped at the start, but nearly all eventually become pumpers. These pumps operate much like any other, being operated by a gas engine or an electric motor.

So to effect the maximum ultimate recovery at the lowest ultimate cost, bottom hole pressures, and the gas-oil ratio — the amount of gas produced with each barrel of oil — are watched constantly and, by means of controls at the well head, the oil is produced at what is considered to be the most efficient rate.

A well could be produced through the casing, but in lifting oil through so large a pipe, much of the gas would bypass the oil and gas-oil ratio would be too great. Accordingly tubing is used. The annular space between tubing and casing may be sealed off near the bottom of the tubing with

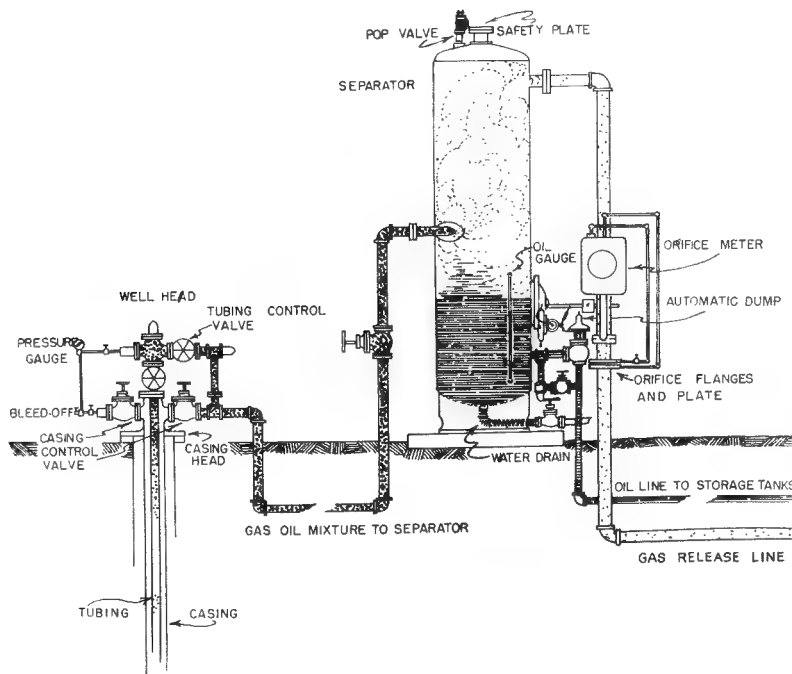


*An oil well  
on pump.*



a steel and rubber device called a "packer." At the top of the tubing, or in the pipes leading from the Christmas tree will be "chokes" which are inserted into and close the lines except for an orifice of specified size regulating the rate of flow from the well.

The flow lines from the Christmas tree take the oil and gas to a "separator"—a cylinder, vertical or horizontal, in which the gas is allowed to expand and its velocity checked. This allows most of the gas to free itself from the oil, it being led away through the gas release line.



*A field separator. Expansion into the separator frees the gas from the oil as indicated.*

This gas from the separator is "wet." It carries considerable of the light gasoline "fractions" which should not be wasted, so once a field is developed, a gasoline plant is often erected to recover from the various wells in the field this "casinghead" gasoline. The plant may be a "compression" plant where the gas is compressed and cooled until it drops the liquid gasoline, or an "absorption plant" where the liquid gasoline is absorbed in oil, and recovered from the oil by

distillation. The residue or "dry" gas is in part used as fuel for the field—drilling, pumping and heating—and the balance will be sold if there is a market for it, may be pumped back into the formation in repressuring, or may be burned in the open air. At one time most was burned. Now everyone is more conservation-minded, and where there is an economic market, or where repressuring is economically feasible, very little gas is wasted.

Some wells, like many in Turner Valley, produce wet gas and no oil. This wet gas is treated much like gas from an oil well, being taken to a gasoline plant and stripped of its gasoline content. In this case, however, the gasoline is not called casinghead gasoline, though of the same general character, but is called "natural gasoline." This type of gasoline is not practical for motor car use but is very valuable for blending with other gasolines at the refinery.

After the gas is separated from it, the oil goes from the separator to a battery of field storage tanks. From the battery it will pass into gathering lines for transmission to the nearest rail point, or direct to the refinery, or in the case of remote or isolated wells, will be taken to the refinery in tank trucks.



*A 'battery'  
in the  
Leduc  
field.*

One might think that once a well is placed on production, no further attention need be paid to it. This is not the case. Leaks in tanks and flow lines need to be watched for and repaired, pumping equipment must be kept in working order, and the well itself must be frequently cleaned. Mud, shale and sand accumulate in the bottom of the well, impeding the flow of oil, and must be removed, and where paraffin base oil is produced, the paraffin congeals along the wall of the tubing or casing and must be scraped or melted off.

At one time, when wooden derricks were the rule, the derrick was left over the well for convenience in taking care of the clean-out jobs. Now the derrick is usually dismantled and removed after the well is placed on production, and a portable truck-mounted rig is used for these operations. The wells must of course be shut down while these operations take place.

Now that industry and government alike recognize the necessity of securing the greatest ultimate recovery of oil and gas, more attention is given to the maintenance of pressure in the reservoir. Frequently as a field begins to decline, an attempt is made to prolong its life by pumping back into the formation, gas which has once done its work in bringing oil or natural gasoline to the surface. This is known as "repressuring," and in some cases it is done from the commencement of production. The gas is compressed to a pressure higher than the reservoir pressure, is forced down "input" wells into the producing horizon, and again does its job of forcing oil into one or more of the wells in the field. When repressuring is applied to a declining field, enabling oil to be recovered which would otherwise remain in the formation, it is termed "secondary recovery."

Another method of secondary recovery is water injection, where water is forced into the producing zone under pressure, driving the oil ahead of it to the producing wells. Water injection is now being experimented with in one area in Turner Valley, with some success. These methods are of course very costly, and cannot be resorted to unless the market price for oil is sufficient to warrant their use.

The problems involved in bringing in a well, and in producing it, are some of those which engage the attention of the petroleum engineer.

## VIII.

# Conservation and Pro-Ration

In the early days of this western country we were very wasteful of all our resources. Land was farmed with no thought of protecting the fertility of the soil. Fish were caught and game was slaughtered as though our supply was inexhaustible. In the lumber industry no attention was given to selective logging or reforestation. So it was with oil and natural gas.

But there came a growing realization that these resources were not inexhaustible, and that methods of exploitation which might at first glance appear to be beneficial to both producer and consumer, reacted in the long run to the detriment of both. People everywhere, and in relation to all our natural resources, became conservation minded.

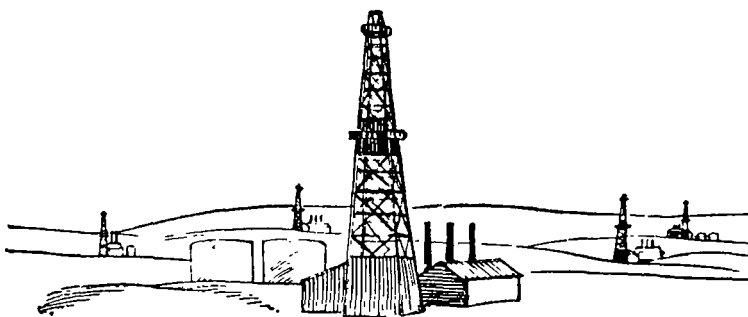
We have seen the advantage of producing a well at a considerably slower rate than is possible. In the oil industry the first conservation methods were instituted by agreement between producers, but frequently one operator would violate the agreement, opening his well wide and forcing others to do likewise, jeopardizing the life of the reservoir. Legislative bodies in the United States began to give their regulatory boards power to enforce conservation methods, and now most oil producing states have conservation laws. Furthermore a number of states have entered into a treaty known as the "Interstate Oil Compact" and their representatives meet frequently to discuss common conservation problems.

In Alberta, the Petroleum and Natural Gas Conservation Board, established by Act of the Legislature, is empowered to prevent the waste of oil or gas. It has jurisdiction to determine the maximum rate of production to be permitted from each well in each field to prevent damage to the reservoir and to ensure within economic limits, the maximum ultimate recovery. It may insist that operators refrain from wasting natural gas, and direct them to invest large sums in gathering lines and compressor stations for the purpose of repressuring gas which

has been produced with oil and for which no market can be found. This Board also regulates well spacing to prevent an operator from drilling near the border of his land and draining off the oil beneath his neighbor's land.

The Board may also allocate the total market available for the oil produced in the Province amongst the producing pools therein, and require that the portion of the market allocated to any pool be shared equitably amongst the wells in the pool. While this power is sometimes referred to as an unreasonable restriction on the rights of the individual operator who might otherwise be able to find his own market for greater production from his own wells, most operators welcome the exercise of the Board's jurisdiction as it discourages wasteful production methods, enables each operator to have a fair share of the market and prevents adverse drainage.

The realization amongst operators of the advantages of orderly and economical production, and the attitude of governments in both Canada and the United States towards waste of this irreplaceable natural resource, have done much to stabilize the industry and to ensure that the greatest possible amount of oil and gas will be recovered, and made available for useful purposes.

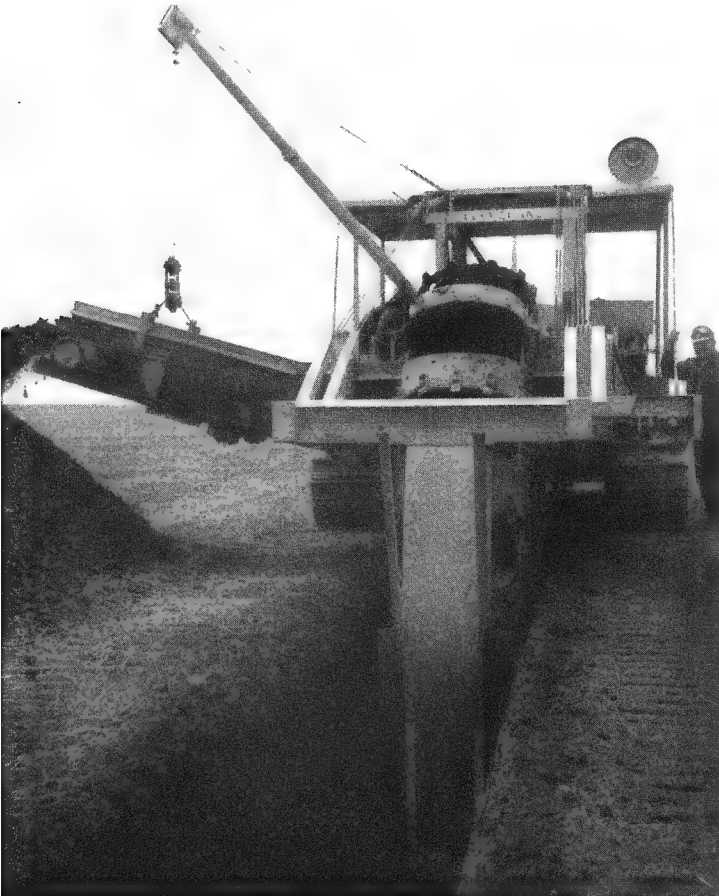


## IX.

# Transportation of Oil

Until the start of the 20th century, oil was usually carried in small barrels in barges, ships, railway cars or wagons. Today crude oil and petroleum products are transported, as a rule in bulk, by pipe line, tanker or barge, tank car or tank truck. All of these originated before the turn of the century but only came into common use during the past 50 years.

We have seen how crude oil is gathered at batteries in the field. From the batteries it usually goes into a gathering system of small lines which accumulate it in tanks at a rail point whence it is pumped into tank cars and shipped to the refineries, or in most developed fields is gathered into a large



*A ditching machine in operation on the Saskatchewan plains*

pipe line leading to the refinery or refineries in the area served by the field.

Pipe lines may be anywhere from 2 inches to 30 inches in diameter. They may carry crude oil or refined products, or both, radioactive substances sometimes being inserted in the last few gallons of one product to permit the operator at the other end of the line, armed with a "Geiger counter" to determine when the next product is about to arrive, and to arrange for diversion of the flow. The lines are constructed of steel lengths welded together. They are coated and wrapped to prevent corrosion, and are buried under the earth. Ingenious machines have been developed to weld the pipe lengths together, to dig the trench for the pipe line, to clean, coat and wrap the pipe and to lay it in the ditch. Pipe lines cross rivers and mountains and the only limitations on their size and length appear to be economic rather than operational. Pumping stations are placed at intervals to maintain the desired rate of flow. Line walkers or small planes flying at low altitude along the line are constantly on the alert to spot breaks in the line.

The United States has an elaborate network of underground petroleum lines over one hundred and fifty thousand miles in extent. Crude oil lines connect the Gulf coast, Oklahoma and West Texas oil fields with Billings, Montana, Salt Lake City, Chicago, Cleveland, and many other producing areas and refinery points located throughout the nation. Lines for refined products run from many of the refineries and coastal points to the principal market areas of the country.

*Side-view  
of a  
ditching  
machine*



Canada until recently had very few oil pipe lines, most of our oil coming into the country by water from pipe line termini on the American side of the Great Lakes and by tank car to inland refineries, although some years ago a crude oil line was built from Portland, Maine to Montreal to transport water-borne crude to the Montreal refineries.

With the development of the western oil fields, however, we are well on the way to having our own network of lines. The Interprovincial Pipe Line recently completed at a cost of some 90 million dollars leads from Redwater to Edmonton, and thence by the most direct route to water transportation on the Great Lakes at Superior, Wisconsin. From this point tankers will take our oil to the refineries at Sarnia, Toronto and elsewhere in Ontario. Branches will lead to this line from the Leduc and other western oil fields, and will connect the line to refineries at Moose Jaw, Regina and Winnipeg. As oil can be transhipped from Superior only during the summer, huge storage facilities are provided at that point to accumulate oil during the season of closed navigation on the lakes, and



*Preparing pipe before laying it. The coating and wrapping machine is shown in the background*



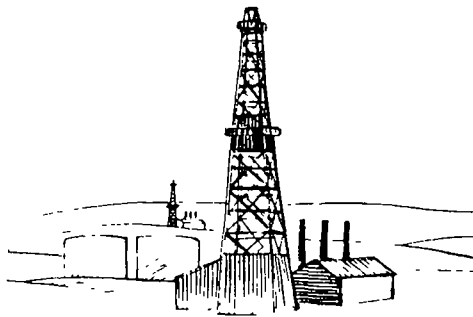
somewhat similar facilities are provided at the Ontario refineries so that sufficient oil can go into storage there during the summer to permit continued operation during the winter. The largest freshwater tankers in the world have been constructed to carry western Canadian oil from Superior to these refineries.

Tankers transport practically all of the oil in international trade and constitute by far the most economical means of transportation. They are, in their simplest form, ships with their hulls divided into oil tight compartments

Railway tank cars are the usual form of land transport of oil where circumstances do not warrant the cost of a pipe line.

Tank trucks are a familiar sight to everyone. They transport crude from fields not yet reached by pipe line and not near rail transportation, but their principal function is in the transportation of refined products from refineries or bulk stations to the filling stations, the industrial users, the farms and the water fronts.

While comparative costs vary greatly, depending on many circumstances, it is generally considered that transportation by pipe line costs about half as much as rail shipment, and that water transport is about half as costly as movement by pipe line.

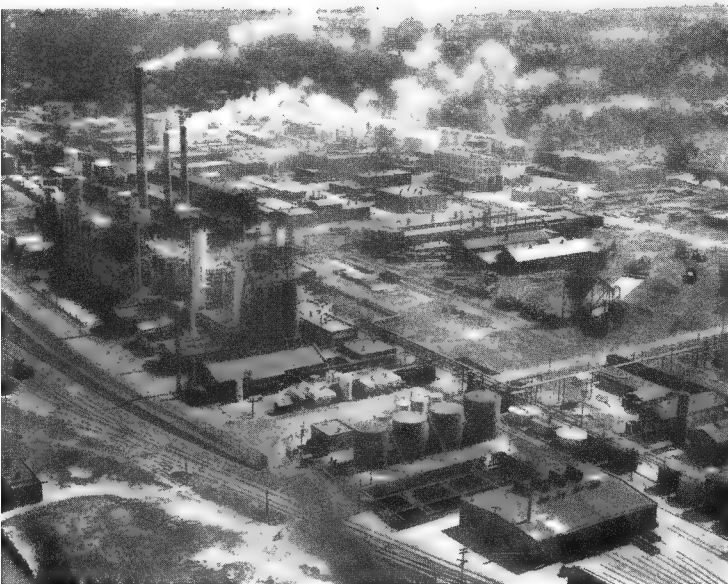


X.

## Oil Refining

Crude oils from different fields have widely varying characteristics. Oil may be rich or wanting in lubricants; it may have a high or low gasoline content; it may have a paraffin base, an asphalt base, or a combination of both. Oils may vary in color, in weight, in viscosity, resulting from variations in composition. These differences may be due to varying source materials, differences in age, differences in the heat and pressure under which they were formed, or differences in the chemicals with which they have come in contact through the ages.

But crude oils have one thing in common; they all consist of compounds of hydrogen and carbon, known as "hydrocarbons." Crude oil is a mixture of these compounds. Natural gas is always associated with the oil and together they form a succession of hydrocarbons from the dry gases at the top of the succession through wet gases, the gasoline series, the kerosine series, the light fuel oils and tractor distillate, heavy fuel



*The refinery of  
Imperial  
Oil Ltd. at  
Sarnia*

oils and lubricating oils to asphalt at the bottom of the succession. Each hydrocarbon is made up of molecules, each having so many hydrogen atoms in combination with so many carbon atoms. Since carbon is about twelve times as heavy as hydrogen, the greater the percentage of hydrogen atoms in each molecule the lighter the hydrocarbon.

Generally speaking, the "lighter" the crude oil, the greater the proportion of light hydrocarbons, and as the gasoline "fraction" is made up of the lightest of the liquid constituents, and since the gasoline market is the most attractive market, oil men are happy when they discover light crude oil. You see from time to time in the paper that such and such well has come in, yielding crude of a specific gravity of 32° or 34° or 40° A.P.I. The larger the specific gravity number assigned, the lighter the crude, measured on the standards prescribed by the American Petroleum Institute. Crudes run the specific gravity range from 5° to 65° A.P.I., with most of the recently discovered western Canadian oils running from 30° to 40° A.P.I.

In its simplest form, refining is nothing more than distillation of the crude oil. It is heated, and as the temperature increases, the hydrocarbons are successively boiled off, the lightest ones first, followed by the next lightest and so on through the entire range. These in turn can be condensed as they vaporize, caught in separate containers and thereby separated. This separation is called "fractionation."

In the simple boiling process, a sharp fractionation of the various products is not obtained, for each "fraction" or "cut" brings with it some of the lighter and heavier cuts. Also such a method is wasteful of heat, so various refinements have been introduced—"flash vaporization" in which the oil is heated to a high temperature and allowed to flash into vapor which is then fractionated in bubble towers, cooled, and the various fractions recovered as they condense; "vacuum distillation" in which both distillation and flash vaporization are done in a partial vacuum which reduces the operating temperature, saves heat, and prevents the breaking down of some of the molecules which might occur at higher temperatures, and "steam distillation" which takes advantage of the fact that water vaporizes at a lower temperature than most oil fractions, so when steam is introduced into a still or flash chamber, the various oil frac-

tions will vaporize at lower temperatures than if steam were not present.

These methods only take out of the oil the constituents already there. The character of the constituents is not changed at all. Products so produced are called "straight run" products, and the process is called "topping" or "skimming".

Until the period just previous to the First World War, that is all that our refineries did, but the demand for various hydrocarbons did not often balance the output. We have seen that in the early days the demand was for kerosine, and gasoline was largely a waste product. Later there developed a great demand for gasoline, with no market for some of the other constituents. To solve this problem—to provide special gasolines for particular motors and particular temperatures, to provide special lubricants for special purposes, and to provide the many products which modern life demands—the refining industry has developed until the present day refinery is no longer limited to sorting out the hydrocarbons contained in the crude, but now breaks down the molecular structure of the hydrocarbons and puts them together into new compounds suited to the particular purposes required.

One of the processes by which these chemical changes are brought about is known as "cracking." In this process, the heavier hydrocarbons are broken down into lighter hydrocarbons. In other words, the refiner can in this way produce more gasoline, less lubricating stock, and less residual fuels.

Cracking may be done thermally, by applying more heat and pressure than required in straight run refining, or catalytically, by heating the crude in the presence of a catalyst—a foreign substance, usually a compound of various metals, which effects a chemical reaction without being itself affected.

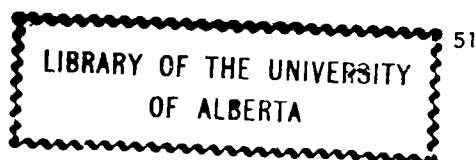
While cracking is the process of breaking down large and complex molecules, like those of the heavier hydrocarbons into smaller and simpler molecules like those of the lighter hydrocarbons, the relatively new process of "polymerization" is the reverse. If fixed or dry gases—those which cannot be liquified at commercial temperatures and pressure—are subjected to appropriate heat and pressure, the components of their mole-

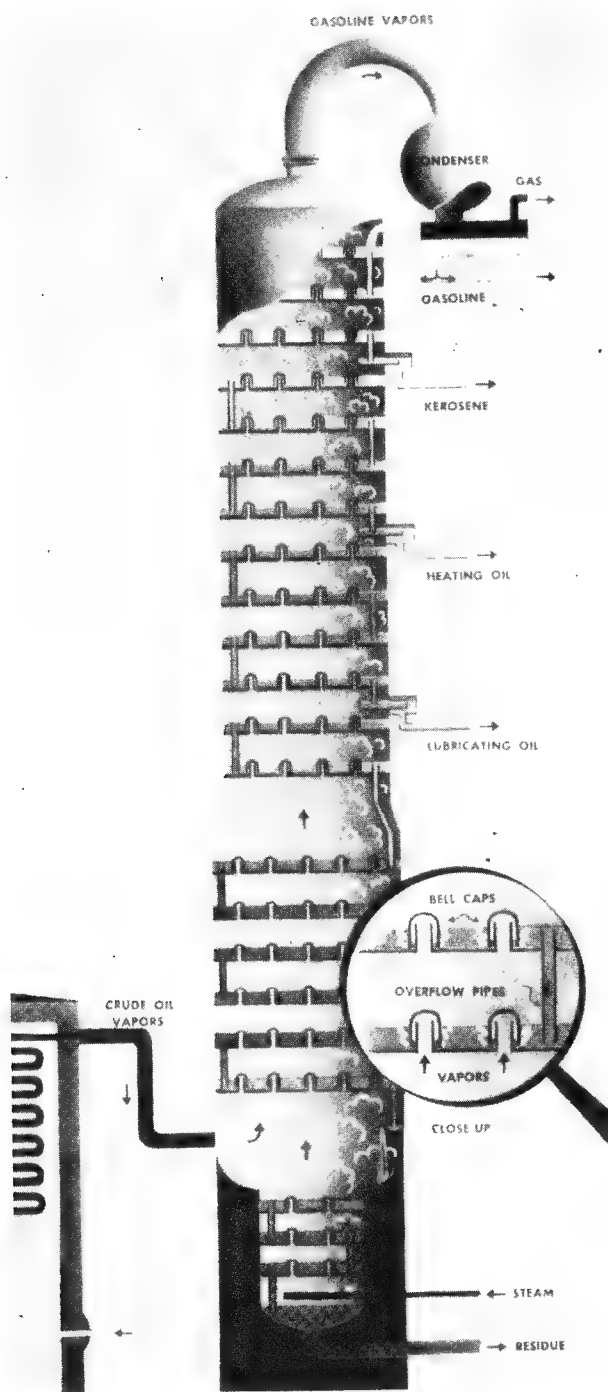
cules can be induced to combine into larger ones, and can be condensed into liquids. In this process, refinery gases can be converted into gasoline

Polymerization is one form of "synthesis." Alkylation, hydrogenation and isomerization are other processes, all useful in producing special purpose gasolines and other products from the hydrocarbons contained in crude oil. None except polymerization is in common use in western Canadian refineries however, with the exception of one alkylation plant in Calgary, so we will not dwell on them longer. In reality they go beyond the normal refining process and are properly classed as processes of the chemical industry.

Refineries vary greatly in design and in the processes used, these being determined by the nature of the crude oil available to the refinery, and in the type of refined products in demand in the refinery's market area. The refineries in western Canada however, operate along somewhat the following lines.

The crude oil enters the refinery by pipe line, or tank car and is placed in large storage tanks. From storage it is pumped into the "pipe still" for initial separation. This is a large heating chamber or chambers around the walls of which are vertical tiers of horizontal pipes, connected together in such a way that crude oil entering one end of the still traverses all the lengths of pipe before it leaves. Heat applied in the still raises the temperature of the crude to that desired. The oil then passes into the "fractionating tower" or "bubble tower" — a vertical steel cylinder which may be as high as a hundred feet or more, with many steel partitions or trays spaced at intervals from near the bottom to the top of the tower. Each tray is perforated with a number of holes and each hole has a chimney a few inches high surrounded and covered by a "bubble" or "bell" cap. These are designed so that liquid in the tray cannot run down through the perforations, but gases rising from below can bubble upwards through the liquid in the tray. In the lower part of the tower, between two of the trays, is the "vaporizer section." The hot oil enters the tower in this section. It is hotter than the boiling point of most of its constituents, so most of it flashes immediately into vapor which starts up through the tower, passing through the perforations in the successive trays. As no heat is applied in the tower, except where superheated steam





*Cut-away sketch of a fractionating or bubble tower.*

is introduced to aid in vaporization as explained earlier in this chapter, the vaporizer section is the hottest part of the tower, and the top is coolest. On each tray therefore is condensed the liquid "fraction" that is condensable at the temperature of that tray.

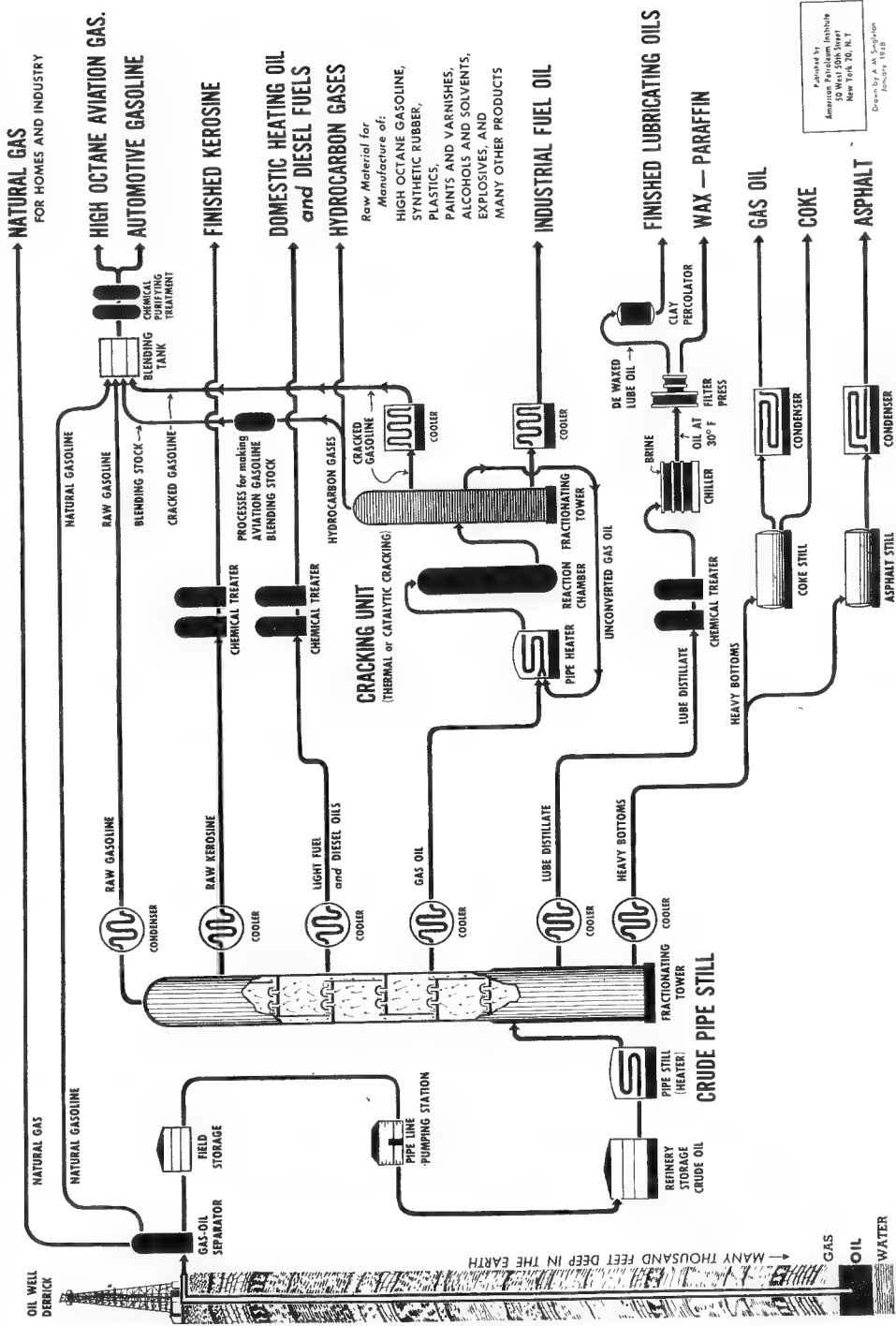
The gases bubbling through that liquid are further cooled and either condensed or if not condensable at that temperature may strip out of the liquid fraction on that tray lighter fractions that have been caught in the condensation and carry them upwards to the higher trays where they condense.

Each tray has a "down pipe" operating like the overflow pipe in an automobile radiator. When each tray fills with liquid to the level of this drain, the liquid spills over to the next tray below where some of it is again vaporized and joins other rising vapors to bubble through and be condensed again on the higher trays. Some of it combines with the liquid in the tray below and overflows from it to lower trays. In this way each particle of oil is vaporized, condensed and vaporized again, sometimes as much as twenty times. Each of these cycles tends to segregate on each tray a more homogeneous fraction more and more free from the lighter and heavier fractions. From some trays, side pipes lead out—one high on the tower taking naphtha, the next lower taking off a light kerosine fraction, the next a "gas oil" fraction and so on.

The lightest vapors do not condense in the tower. They go on out the top and through a condenser where some of the vapors are condensed into a liquid—usually gasoline, and the remainder—fixed gas that won't condense at ordinary temperatures—goes into a gas separator and thence to a gasoline plant where any fractions that may be liquified are removed in much the same manner as natural gasoline is obtained from field oil and gas as explained in the chapter "Producing an Oil Well." The dry gas remaining is used as a fuel or goes to the "polymer section" where part may be polymerized into gasoline.

The part of the oil that does not vaporize in the tower collects on the tray at the bottom of the vaporizer section, overflows into the next tray below, and so on. In each step of its descent it is subjected to oil and steam vapors bubbling up through the trays and is stripped of the lighter constituents, and the heavy residue is drawn off at the bottom.

**Typical FLOW CHART tracing Crude Oil from well to finished products**



Published by  
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New York 20, N. Y.

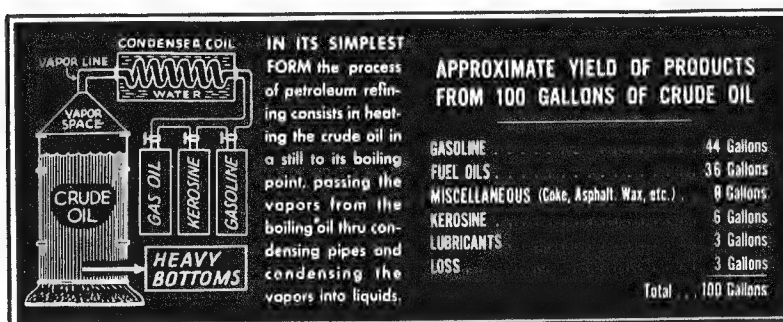
Drawn by A. M. Singleton  
January 1948



This fractionating tower is the heart of the refinery, but by no means all of it. Many of the products drawn off the tower require further processing to fit them for market. Redistillation is used to improve the quality of some of the products. The heavy "bottom" for example may be redistilled and put through other fractionating towers, some emerging as asphalt, some as lubricating oil and paraffin, and some as coke. If a cracker is used, and it is simply another fractioning tower with adjusted temperatures and with possibly the addition of a catalyst, some may emerge as cracked gasoline to mix with straight run and natural gasoline to form a premium motor fuel.

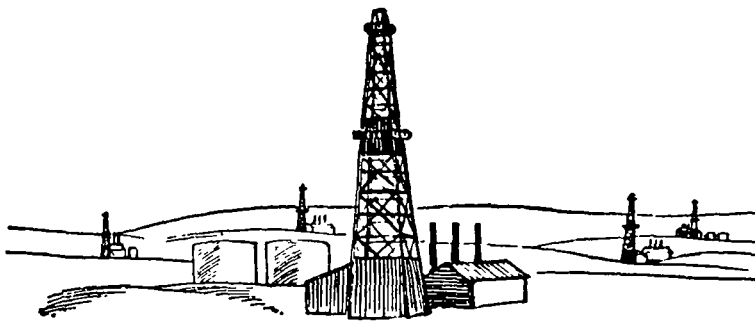
And further distillation or cracking is not the only treatment required. Lubricating oil must be dewaxed, treated with acid and clay to remove impurities and stabilize the color, and given solvent treatment to improve its viscosity. Kerosine and gasolines must be chemically treated to remove sulphur, resins, gums, and other impurities and to improve color, odor and stability.

Mixing of gasolines too is an important function of the refinery in producing the type of fuel required. What is not commonly known is that western Canadian refineries must vary their product from time to time depending on the prevailing climatic conditions. Gasoline which is sufficiently volatile to provide easy starting of automobiles in extreme winter temperatures would cause "vapor lock" if used as a summer fuel, just as one sufficiently heavy for summer use would fail to vaporize rapidly enough for easy starting on a sub-zero day. The availability of just the right amount of the right type of gasoline at the time of need is one of the constant problems of western Canadian refineries.



As times change the demand for products changes, and since the end of World War II the manufacture and use of oil burning heaters for home heating has expanded at a most unexpected rate. This upsets the balance of the refinery stocks, as the heating oils are the fractions which would ordinarily make up the feed for the cracking units, and these units are then short of feed stock. However, with new type cracking equipment, such as fluid catalytic cracking units, deeper cuts can be made into the residual fractions of the crude and balance again achieved, without letting a householder go cold.

While we are rapidly approaching the day when any part of the crude oil may be considered nothing more than a raw material that may be converted at will into any desired product, the equipment for a single refinery operation may cost in the millions of dollars, and this cost, balanced against the demand for the resulting product, must always be the governing factor.

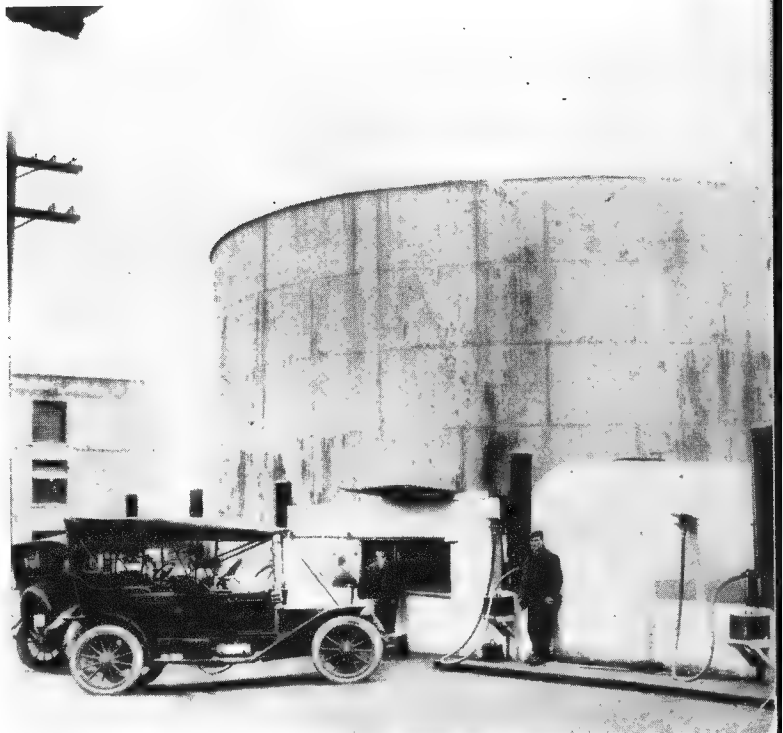


## Marketing of Petroleum Products

Have you ever considered, when asking your filling station operator to "fill 'er up" just how gigantic is the task of organizing distribution of petroleum products so that even in the most remote areas the right amount of the right product is available at the right time?

At the beginning of this century when kerosine and lubricating oils were the only petroleum products in wide use, you would have bought kerosine for your lamps from the grocery or hardware store unless you lived where peddlers made door to door deliveries, drawing the amount required from a tank mounted on a small horse-drawn wagon. If you required gasoline you bought it probably from a drug store under the name "benzine." Lubricating oils and greases were bought at the hardware. Even then however, the bulk plants were in exist-

*Canada's  
first  
service  
station —  
Vancouver  
1908*



ence—places where tank car, barge or other large shipments were broken into tank wagon, barrel or smaller-package quantities for local delivery. Kerosine was laboriously transferred at the bulk station with hand pumps.

The development of the motor car brought about a gradual change. By 1910 there were half a million automobiles on this continent, but even then the motorist in most places had to fill his tank with measuring can and funnel. However, before the end of World War I, a number of men had gone into business as oilmerchants, and the "service station" was born — an institution with which we are all familiar.

These service stations frequently carry the banner of one or another of the large oil refining and distributing companies whose products are handled there, but that does not signify their ownership. In a few cases they are operated by the oil company through a salaried manager. In some cases they are owned by the company and leased to the operator and in many cases the operator owns the station.

As no station operator can do much to increase the total gallonage in his district, his success is determined by how much of the existing market he can take away from his competitors. This has led to rapid improvement in station appearance and cleanliness, in service to customers, and in mechanical devices enabling him to serve his customers efficiently and with the least possible delay. As a result of this competition, the service stations are now in most cases about the most attractive and well kept business premises in our towns and villages.

Delivery of the product to the underground tanks at the station is made by a large tank truck—a familiar sight on the highway—from a bulk station.



*A modern  
service  
station*

The bulk station operator is the wholesaler or jobber of petroleum products. Usually an independent contractor, operating an establishment owned by the company, he buys the company's products or receives them on consignment, delivers them in trucks owned by himself and takes a mark-up agreed between himself and the company. He handles his own credits and is responsible for any losses. At key points he may also receive and trans-ship products to other bulk dealers at smaller points receiving in such case only his transportation costs and a handling charge. The bulk station also sells at retail to farmers for tractor and general farm use, and for heating.

Until very recently, many of the farm deliveries were made by barrel; now tank truck delivery is the rule, the gas or fuel oil being metered into barrels or storage tanks at the farm. The barrels are charged by the company to the bulk dealer and he has to account for them periodically. Some farmers save delivery costs by calling at the station for barrels of gasoline, distillate, or oil for heating. More and more farmers however are installing at their farms large tanks with a capacity of 200 gallons or more as they provide a more continuous supply, prevent waste, and being placed on racks some distance above the ground, make it much easier to service tractor or truck.

The bulk dealer also supplies kerosine and lubricating oils and greases to the hardware stores and other dealers, and distributes fuel oil to those who use oil for heating.

In large centres the oil company usually takes care of its own distribution to service stations, and to fuel oil users in the city, operating its own bulk station, though even in such cases there is as a rule a local agent operating much like the bulk dealer in the smaller towns, except that he has no storage tanks and such facilities, who services the requirements of the surrounding farm population.

Large users—public carriers, aviation companies, manufacturing plants, government agencies, and the like, usually buy their requirements direct from an oil company after having received competitive bids from several.

Marine requirements are met in a number of ways. Small craft such as pleasure boats and small fishing vessels, fill their

tanks at a marine service station anchored off shore and operating much like a service station on land. Ocean going and lake vessels operating with heavy fuel oil are bunkered by lighters operating from large terminals or refineries.

In some cases, distributing companies operating on a large scale, have nothing to do with oil production or refining, but are marketers only, or sometimes blenders and compounders as well. This is particularly true in the field of lubricating oils and greases. Such firms buy the components from refiners and mix them to form the product desired. These companies, as well as the larger refiners, often supply experts to consult with large consumers, advising them on their lubricating problems and producing special lubricants to meet their needs.

Many of the specialties and chemicals are sold direct from the refineries. Thinners are sold to the paint and varnish manufacturers, paraffin sales are made to the fabricators of wax paper, waxed containers, matches and shoe polish. Special petrolatums used as a base for salves, cold creams, and cosmetics are sold to the drug houses and the cosmetic manufacturers.

Many other specialties, sheep dip, hog oil, harness oil, dry cleaning fluids, insecticide and anti-freeze, to name a few, are handled through the bulk station like gasoline and oil.

There is no hard and fast pattern to the distribution of petroleum products. Methods of distribution are constantly being varied to meet existing conditions, and as the industry is highly competitive, any additional service that can be supplied to the consumer, any saving that can be made in the cost of distribution, is quickly seized upon by the company discovering it.

## XII.

# Pricing of Crude Oil and Refined Products

The producer of any commodity wants to get as much money as possible for his product, but often has little control over his financial return. In the case of a commodity that flows in international commerce and with respect to which several areas have an exportable surplus the price to the producer depends on the competitive position at the most distant point of consumption, and the cost of transportation to that point.

These factors which apply to many other commodities, also determine the field price of crude oil. Until recently Winnipeg was the most distant market for our oil. The price there had to be such as to compete with the laid down cost of oil from Illinois. The western field price was simply that cost, less the cost of transportation from the field.

Prior to the completion of the pipe-line to the Great Lakes, western oil could not successfully compete in the Ontario market, since the high cost of transportation, deducted from the cost of alternative supplies at the Ontario refining centres, would leave the field price at a figure below that at which it was worth while for western producers to sell.

But now that western oil is beginning to move by pipeline and tanker to the refineries in Ontario, Sarnia is replacing Winnipeg as the key, or fringe market, and the competitive conditions at Sarnia will govern the price of crude in the western oil fields. This movement has resulted in a reduction in the field price since Sarnia is closer to alternative supplies and more distant from ours, but the saving in transportation costs through the building of the pipeline will enable our producers to sell in that market. Though they may be obliged to accept a lower price, this loss will be more than offset by the gain through increased sales.

No one can forecast with accuracy what the Sarnia price will be from time to time. World supply and demand may

change the present price. But no matter what happens to world prices, the field price of western crude is sure to be less than it would have been if the movement of that crude to Ontario had not taken place.

The prices of refined products generally follow crude prices, but not proportionately. Labor costs, material costs, cost of transportation of refined products, and taxes all play a large part in the cost of the finished product to the consumer, and these may remain the same, or go up, while the cost of crude goes down. But here again, any reduction in local crude oil prices is bound to make the price of gasoline or any other petroleum product refined from that crude less than it would be had not that reduction in crude oil price occurred.

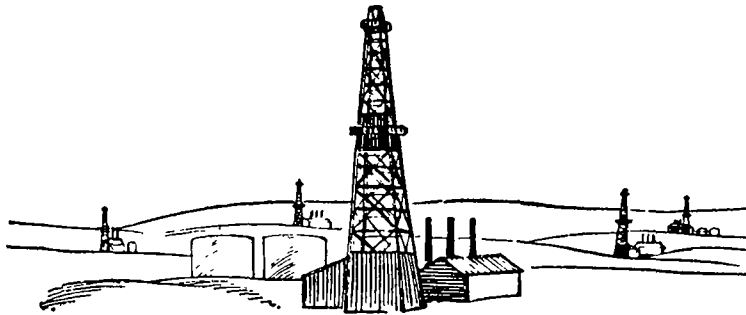
It follows that any development which brings a new market for western oil is bound to react to the benefit of western consumers of refined products. It has been established that in 1949, prairie consumers would have spent 30 million dollars more for petroleum products if crude from the new Alberta fields had not been available. In 1950, thanks in part to the pipeline, this saving was 35 million dollars. In 1951 it is estimated to reach 55 million dollars. If new oil fields and new markets and marketing facilities are developed, it may be much more in the future.

In comparing gasoline prices with crude oil prices, we sometimes forget many of the things that enter into the final price. In order to realize the refiner's position let us look first at what he does not receive when the customer buys a gallon of gasoline at the pump. From the consumer's price must first be deducted the provincial gasoline tax of 9c or 10c per gallon, depending on which western province we are considering. Next must be deducted the margin set by the proprietor of the service station which will be from 4c to 7c per gallon, depending on the competitive situation in his area. Then we must take off the cost of transportation from the refinery which, depending on how remote is the dealer's station from the refinery, will run from 3c to 15c per gallon. Lastly must be deducted the sales tax of from 1c to 2c per gallon. From 17c to 34c per gallon therefore, or roughly half of the price paid by the purchaser, never comes into the hands of the refiner.



Out of what the refiner does receive, he must pay for his crude oil, and must take care of his refining costs. He expects of course to make a profit too, but whether he does or not and how much his profit is, depends to a great extent on matters beyond his control. His selling price is determined largely by competition from other refiners who may be better located with respect to a portion of his market, or who have a lower investment by reason of refinery construction at a time of lower costs. Refiners' profits vary greatly, but seldom exceed 1c per gallon.

From January 1947 to December 1950, the cost of living in three representative cities in the Prairie Provinces had increased 33.5%. Food had increased in price 52.3% and clothing 45%. During the same period gasoline had increased in retail price 8.8%. Thanks to local discoveries, new refineries and new outlets to market, gasoline prices have largely held their own, in spite of substantial increases in other living costs.



## Financing Oil Developments

From what has been said in the preceding chapters, the reader will realize that oil exploration requires a vast amount of capital, and that it must be "risk" or "venture" capital. It requires the type of investor who is prepared to take a long chance, knowing that the odds greatly favor the loss of his capital, in the hope of a substantial profit if he is lucky.

For unlike most businesses, where stock in trade may be acquired readily at prices reasonably well known in advance, the oil industry has to find its stock in trade—its reserves of crude oil—and the cost of finding, and whether it will be found at all, must ever remain an uncertainty

In 1949 the oil industry spent in exploration and development alone in western Canada, somewhat more than 100 million dollars, and it recovered oil, over and above royalties, to a value of around 50 millions. In 1950 it spent 150 millions and oil to a value of 73 millions, excluding royalties, was produced. The industry's total Canadian investment for 1950, including pipeline and refinery construction, was about 278 million dollars.

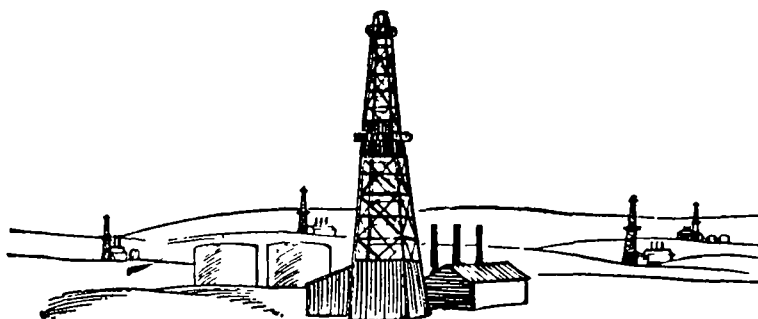
It is estimated that to find the reserves and develop refining and marketing facilities to supply crude oil to the extent of Canada's total demand will require further capital investment of somewhere between three-quarters of a billion and one billion dollars.

It is obvious that this requires the participation of vast amounts of capital from sources outside the Canadian oil industry, since it will be many years before that industry, out of current income, can hope to finance its own exploration. Indeed, there are many companies now engaged in the oil business in western Canada who have each spent as much as several million dollars without finding a single barrel of oil.

This money can only come from three sources. Some of it can come from the reserves of major oil companies, built up

over the years out of profitable operations in other lands. Some may represent the earnings of other businesses—reinvested in the oil industry. The rest of it must come through the sale of shares, bonds and debentures—the traditional method by which corporations are financed—and will represent the savings of individuals. One need only to call at any brokerage office in any western Canadian city to see whose money is participating in western oil development. There, anxiously watching the board to check the trading activities in their favorite oil stock, will be seen mechanics, clerks, stenographers and housewives, as well as farmers, merchants, school teachers, doctors, and other business and professional people.

Hundreds of thousands of Canadians, from all walks of life, are participating, by their investments, in the Canadian oil industry



#### XIV.

## Conclusion

We trust that the foregoing pages have given the reader some understanding of the fundamentals of the oil industry. The various steps from exploration to marketing have been presented in their simplest form, since it is patently impossible to deal with all of the problems encountered by such a complex industry in the few pages which this booklet contains.

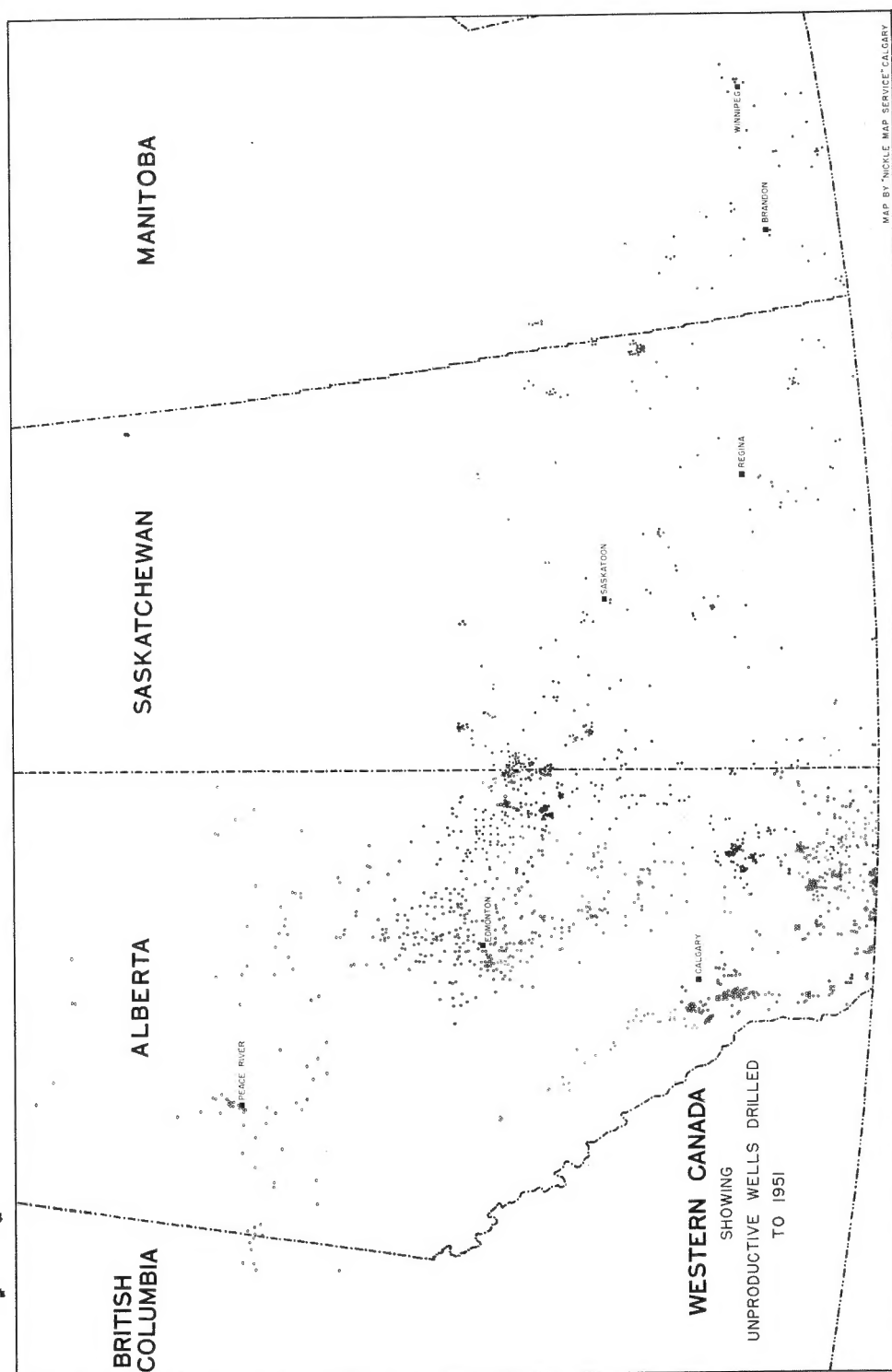
Wherever oil is used, it contributes to man's standard of living. In Canada today our per capita consumption of oil is higher than that of any other country except the United States, and our standard of living reflects this. In recent years Canada as a whole, and Western Canada in particular, has enjoyed still further benefits from oil through increased local production.

Possibly the greatest benefit is the increase in mechanization of farming which is due in large part to Western Canada's transition from a high cost to a low cost oil area. Savings to prairie oil consumers as a result of the Western oil discoveries were dealt with in an earlier chapter. While this has had a direct effect on the prairies, it has had an effect on Canada as a whole, for anything which contributes to lower cost of production for the farmer will in the long run be of benefit to the national economy.

And we are gaining in other ways

On the national scale, one of the outstanding results of Western oil production has been an easing of one of Canada's major economic problems—the shortage of U.S. dollars. The savings in this direction have increased as oil production has increased. It is estimated that in 1950 Western oil production, backing out imported oil, saved our country 150 million dollars in foreign exchange. This means that we in Canada have more U.S. dollars available to buy things which we do not grow or manufacture in our own country.

Being closest to the new fields, Albertans have reaped the most direct benefits. The large sums of money which have



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been realized by the Alberta Government are contributing substantially to the development of that Province. The oil development has also meant many new jobs in Alberta; it is estimated that between 1947 and 1950 about 8,000 new jobs were directly traceable to the oil industry. Discoveries in other provinces will secure similar results for their residents.

These benefits we shall continue to reap as long as the activities of the industry in the West continue. But the future may bring much more. The presence of oil and natural gas in large quantities is likely to bring to Western Canada a degree of industrial development beyond our fondest hopes.

Agriculture is, and will continue to be, the backbone of our prairie economy but industrial expansion can provide the difference between an average and a better than average standard of living. Industrial development fostered by the oil discoveries will result in a better balanced economy throughout the West.

The extent of the benefits that we receive will, of course, be in almost direct ratio to the extent, and the success, of the search for oil.

Our present reserves of about 1,100,000,000 barrels will need to be more than doubled if oil equivalent to Canada's total consumption is to be produced. Sedimentary rocks, in which oil may be found, extend all the way from the Arctic to the United States border, and from the Rockies into south-western Manitoba, and this vast area has barely been touched in spite of the extensive drilling of the past few years. Both of these circumstances invite further exploration.

Exploration must, however, be attended with some degree of success if it is to continue. Frequent disappointment is to be expected; the "dry hole" map on the opposite page indicates the disappointments of the past. But if there are sufficient successes to offset the failures, enough discoveries to warrant a continued program of exploration, Western Canada will realize the maximum benefit from the activities of the oil industry.

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